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Risk estimation in international futures markets : an anaysis of trading/non-trading time and information effects.

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RISK ESTIMATION IN INTERNATIONAL FUTURES MARKETS:
AN ANAYSIS OF TRADING/NON-TRADING TIME
AND INFORMATION EFFECTS

A Dissertation Presented

by

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ABSTRACT

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AN ANALYSIS OF TRADING/NON-TRADING TIME
AND INFORMATION EFFECTS

May 1990

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Asset risk is one of the principal parameters in various financial models. A growing body of academic literature has examined the characteristics of risk as measured by the variance of the return distributions for various assets. While extensive analysis has been undertaken on the trading/non-trading time effect in variance patterns for assets traded in the United States financial markets, relatively little research exists for the variance patterns of assets which have multiple market listings in the U.S. and other countries. Empirical studies which have considered the variance distributions only in the context of U.S. market trading and non-trading periods have failed to properly address the potential effect of trading periods in foreign markets on the variance patterns of assets with world-wide markets which can differ from those observed for assets traded in the U.S. markets only.

This study investigates the trading/non-trading time effect in the distribution of variances for the U.S. Treasury bond futures and Eurodollar futures contracts presently traded in the United States, Europe, and Far East. The effect of information arrival on the distributions of variances is also examined. Results show that variances differ both between trading and non-trading periods and between the trading periods of different markets. In addition, the analysis also indicates that the impact of macroinformation generated in the U.S. is more pronounced than the impact of similar information generated in major overseas markets on the variance patterns of the U.S. Treasury bond futures and Eurodollar futures.

In view of the increasingly integrated international financial markets, the results of this analysis have important implications for various investment strategies. If asset risk vary significantly across trading and non-trading periods of individual markets, model specifications should be adjusted for the nonstationarity of risk estimates.

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CHAPTER 1

INTRODUCTION

1.1 Background

Asset risk, as measured by return variance, is one of the principal parameters in various financial models. Portfolio selection models (e.g., Markowitz mean/variance analysis) require variances (and covariances) as crucial inputs in the determination of efficient portfolios. Likewise, general equilibrium models, such as the Sharpe/Mossin/Lintner Capital Asset Pricing Model (CAPM) and its variants, show that the variance/covariance structure of all traded assets is a major determinant of an asset's systematic risk (beta) thus, its expected return. Variance estimate is also a critical variable in financial models involving derivative assets. According to the Black and Scholes Option Model, the value of an option is a function of the instantaneous return variance of the underlying asset. For commodity as well as financial futures, hedging models provide optimal ratios of futures position to the cash position that are affected by the variance of the futures as well as cash assets.

Risk as measured by variance, therefore, has a significant impact on the performance of basic financial models which form the foundations of various trading strategies. Moreover, variance estimation is a principal concern to empirical researchers who require an estimated value of current asset risk in testing pricing models as well as in forecasting future values of return distribution parameters. Variance of asset returns, however, may not remain constant over time. Failure to adjust for non-constant variance can cause some of the tested model's attributes to be missestimated (see, for example, Barry [8], Giovanini and Jorion [59] on tests of CAPM with time-varying return variance, and French [52] on tests of the Black and Scholes Option Model with non-constant variance rate). Variance nonstationarity can also affect the forecast precision of models using time series data (for example, Akgiray [3] demonstrates that time series models which allow for conditional heteroskedastic return variance can provide improved forecasts of daily volatility).

A growing body of academic literature has provided evidence that return variance of various assets can be non-stationary across calendar months, weekdays, as well as time periods within a day (e.g., Fama [45], French, Keim and Staumbaugh [86], French and Roll [54]).[1] In this proposed study, the focus of the analysis will be on the nonstationarity in the pattern of variance across trading and non-trading time periods, i.e., the trading/non-trading time effect. Trading time refers to the time periods during which the principal markets (e.g., the New York Stock Exchange for stocks, the Chicago Board of Trade and the

Chicago Merchantile Exchange for futures contracts) or an active over-the-counter market are open for security trading. Non-trading time encompasses the periods during which the exchanges are closed.[2] Several studies have documented the trading/non-trading time effect in the stock markets. For instance, Oldfield and Rogalski [105] and French and Roll [54] show that the stock return variance over the trading hours of the New York Stock Exchange is significantly greater than the variance over the weekend non-trading hours when the exchange is closed.

Evidence of trading/non-trading time effect in return variance are not limited to those from stock markets. Hill, Schneeweis, and Yau [72], and Lauterbach and Monroe [92] have shown that for various financial as well as commodity futures, variance can vary significantly across across trading and non-trading hours of futures exchanges. Ito and Roley [78, 79] have reported that variance is non-constant across intraday time periods in the foreign exchange market for U.S. dollar/Japanese Yen. While these studies are based on different assets, their results suggest that return variance over trading hours of the major exchanges is significantly higher than the variance observed over non-trading hours when the exchanges are closed.[3]

1.2 Motivation and Scope of Study

While the trading/non-trading time effect in the pattern of variance for various assets has been well documented in the literature, the observed differential between variances measured over trading and non-trading periods of major exchanges has not been fully explained.[4] Moreover, previous empirical studies which have focused exclusively on the trading/non-trading time effect in the U.S. markets have not properly considered the impact of extended trading hours for assets that are traded internationally.[5] The intertemporal pattern of risk estimates across trading and non-trading periods for assets with multiple listings in various international markets can differ substantially from those of assets with listings in U.S. markets only. Studies which have used only U.S. market closing prices to estimate daily variance for assets traded world-wide (e.g., Makhija and Nachtman [93]) have not examined changes in variance across the trading and non-trading hours of international markets that can occur after U.S. markets are closed. Variance estimated from U.S. market close-to-close price changes may not accurately reflect the true pattern of intraday volatility of asset price movements that is also affected by overseas trading. In short, results of studies which have mainly focused on the nonstationarity of return variance for assets traded in the U.S. financial markets only may not apply directly to assets that are traded internationally.

In this study, an empirical investigation of the pattern of risk (as measured by return variance) for the U.S.

Treasury bond futures and Eurodollar futures contracts which are traded in the United States as well as in Europe and the Far East is undertaken. By considering assets with multiple listings in international markets, the results of the study offer additional insight on the trading/non-trading time effect in the distribution of return variances. Of equal importance, given the current progress towards closer linkages among financial markets around the world, nonstationarity of return variance has implications for investment decisions involving assets that are traded world-wide. For global investors, the relevant risk estimates are those that reflect the volatility in the home market as well as in foreign markets. These investors would need to adjust their trading strategies to the extent that risk estimates vary significantly between trading and non-trading hours of individual markets that are open during various times of the day.

To examine the trading/non-trading time effect in international futures markets tests are performed to determine whether return variances differ significantly across trading and non-trading sessions of the markets in which the U.S. Treasury bond futures and Eurodollar futures contracts are traded. These two contracts are among the most popular investment vehicles used by investors in managing the exposure of their portfolios to interest rate risks. Alternative variance estimators based on daily opening, closing, high and low prices from different markets are used to analyze the pattern of variance over the 24-hour period. The results should indicate whether the observed patterns of variances are consistent with alternative explanations including the calendar time, transaction time, and information/transaction cost hypotheses.

Tests of trading/non-trading time effect in the distribution of variances are also performed for different subsamples to assess any seasonality and maturity impact on the time patterns of estimated variances (e.g., intradaily, daily, and monthly patterns). Alternative partitions of the sample allows the interaction effects of various seasonalities (e.g., by year and contract month) on the intertemporal stability of variances for the two futures contracts to be examined. In addition, the impact of holidays and weekends on the volatility of futures contracts prices will be analyzed to determine whether "weekend and holiday effects" exist in the pattern of estimated risk for assets traded in international markets.

A fundamental proposition in the theory of competitive financial markets is that asset prices change in response to the arrival of information as investors revise their expectations about the distribution of future cash flows of the assets. A number of studies have also suggested that the trading/non-trading time effect in return variance is related to the uneven arrivals of information through time (e.g., French and Roll [54], Jordan, Seale, Dinehart, and Kenyon [81]).[6] In this dissertation, an investigation of the relationship between trading/non-trading time and information arrival effects for the U.S. Treasury bond futures and Eurodollar futures contracts is undertaken. The increased integration of international financial markets and advances in telecommunication technology has led to a greatly expanded set of information relevant to assets with multiple listings in markets world-wide. For these assets, the variability of their returns are affected not only by information generated in the home market but also by additional information released in overseas markets. To examine the extent to which uneven clustering of information flow affects the estimation of variance for the U.S. Treasury bond futures and Eurodollar futures contracts, the impact of macroinformation released in the U.S. and other major markets (United Kingdom and Japan) on the variance pattern across trading and non-trading hours of the markets for the two futures contracts is analyzed. By including foreign news releases in the information environment, it is possible to examine the relative impact of domestic and foreign information flows on the pattern of variance for the internationally traded U.S. Treasury bond futures and Eurodollar futures contracts. To the extent that releases of relevant macroinformation lead to high volatility on certain days then it may be possible to develop profitable trading strategies based on the pattern of changing variances in international markets.

The remainder of this dissertation is organized as follows. The review of literature pertaining to trading/non-trading time and information effects on the estimation of asset risk is presented in Chapter 2. The data, testable hypotheses, and research methodology is described in Chapter 3. The empirical results are presented in Chapter 4 and the conclusion of this study and directions of future research is discussed in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Asset Risk and Financial Models

In financial research, asset risk is commonly represented by the variance of return distribution. Missestimation of variance as a surrogate of risk may have serious implications for tests of asset valuation.[7] Barry [8] shows that failure to recognize nonstationarity of parameters can lead to a missestimation of some of the attributes of the CAPM. In a recent study, Giovanini and Jorion [59] conduct empirical tests of the CAPM using alternative specifications of the time varying second moments (variances) of returns. While their results cannot fully explain the time variation in risk-premia, they do suggest that a thoroughly satisfactory test of the CAPM will require a much more complete specification of the time varying conditional return variance process than those examined in the study. Hull [75] points out that nonstationarity in the variance of the underlying asset can affect the Black and Scholes option prices. Hull further suggests that if volatility is largely related to trading days, then the variance parameter in the option pricing model should be estimated over the trading days. Examining the implications of weekend effect in the distribution of stock prices on option pricing, French [52] also suggests that two time measures should be calculated when options are being valued. French argues that two separate time measures are necessary since stock return variance appears to be related to trading days while interest payment is on calendar day basis. Examples of financial models which require return variance as a major parameter are presented in Table 1 (p.11).

2.2 Nonstationarity of Asset Return Variance

Evidence of nonstationarity of asset risk has been documented in several studies. For example, Bonin and Moses [17], Merton [98], and Officer [104], among others, report seasonality in the pattern of monthly stock return variance.[8] Schneeweis and Woolridge [118] examine seasonal changes in risk (variance and beta) as a possible explanation for the observed seasonality in monthly U.S. Treasury, corporate, and utility bond returns. A growing body of academic literature has also investigated the patterns of risk over shorter time intervals, e.g., daily and intradaily periods. Since the main objective of this study is to examine the pattern of asset risk as measured by variance across trading and non-trading periods during the 24-hour day, the relevant literature review encompasses studies which are primarily concerned with the characteristics of daily and intradaily variance distributions.

TABLE 1

Examples of Financial Models Requiring Variance Estimation.

Cash Assets

1. Mean/Variance-based Portfolio Selection Model
   - Markowitz Efficient Portfolio Selection

2. General Equilibrium Pricing Models

   - Two-Moment Capital Asset Pricing Model
     Sharpe/Mossin/Lintner CAPM

   - Three-Moment Capital Asset Pricing Model
     Klaus and Litzenberger 3-Moment CAPM

Derivative Assets

1. Options *
   - Black and Scholes Stock Option Pricing Model
   - Black and Scholes Stock Option Pricing with Stochastic volatility
   - Black and Scholes Stock Option Model with Time Measure Adjustments
   - Black and Scholes Stock Index Option Pricing Model
   - Black and Scholes-based Bond Option Pricing Model
   - Black and Scholes Currency Option Pricing Model
   - Black and Scholes Option on Futures Pricing Model

2. Futures **
   - Basic Cost-of-Carry Model
   - Minimum-Risk Hedging Model with futures
   - Portfolio Optimization Model with cash and futures

* For details of various variants of the Black and Scholes basic call option formula, see Ritchken [111], Hull [75].
** For cost-of-carry models for other futures contracts (e.g., stock index futures, cuurency futures), see Schwarz, Hill, and Schneeweis [120], Hull [75]).

Nonstationarity in asset return variance has often been discussed in the context of calendar time and transaction time hypotheses. The calendar time hypothesis posits that the stationary asset return generating process operates continuously in calendar time with independent and identically distributed returns. The main prediction of the calendar time hypothesis is that the mean return and the variance of return associated with a buy-and-hold strategy measured from Friday's closing price to Monday's closing price will be three times the mean return and variance of the same strategy with the mean return and variance based on the closing price on a weekday to the next day's closing price. According to this hypothesis, the estimated mean return and variance are a function of the length of holding period measured in chronological time.

In contrast to the calendar time hypothesis, the transaction time hypothesis maintains that the stock return generating process operates continuously during trading time only. Thus, the transaction time hypothesis predicts that for the buy-and-hold strategy, the weekend return and variance should be identical to the weekday mean return and variance since both holding periods contain one trading day. The relevant time interval is, therefore, the trading period, i.e., the period during which the major markets for the asset are open.

The calendar time and transaction time hypotheses have been extensively tested in several studies involving the nonstationarity of stock return variance. Fama [45] compares daily return variance for weekdays (e.g., Wednesday close to Thursday close) with return variance over the weekend (Friday close to Monday close) and over holidays for eleven randomly selected Dow Jones Industrial stocks for the period 1957-1962.[9] The calendar time hypothesis predicts that the ratio of weekend and holiday variance to weekday variance should be about 3. However, if the stock return generating process only operates during the trading time as described by the transaction time hypothesis, the ratio should be about 1. The average variance ratio for the stock sample considered by Fama indicates that the weekend and holiday variance is only about 22% higher than the weekday variance. While the results of Fama's study suggest that the weekend and holiday variance may be systematically different from the weekday variance, they fail to provide support for either the calendar time or transaction time hypotheses as an explanation for the observed pattern in the interday variance distribution.

French [53] and Keim and Stambaugh [86] examine the average daily return on the standard and Poor's 500 Index. French reports that the weekend variance is approximately 42% higher than the average weekday variance. Keim and Staumbaugh also find a significant difference between the average weekend and weekday variances. In addition, the authors document a pattern of decreasing daily variance of the S&P 500 during the week. The results of both studies are therefore consistent with those of Fama's. The variance of common stock is found to differ over weekend and weekday. Moreover, the distribution of variance appears to exhibit a daily pattern.

To investigate variance nonstationarity further, other studies examine stock return movements during the opening and closing hours of the exchanges separately. Using transactional data for five NYSE stocks for the period October 1974 to December 1977, Oldfield and Rogalski [105] compare the variances of returns calculated from Friday's closing price to Monday's opening price (weekend); day t's closing price to day t+1's opening price (overnight); day t's opening price to day t's closing price (daily). Oldfield and Rogalski find the daily variance (.000356) to be higher than the weekend variance (.0001396). Since the daily and weekend variances as measured in Oldfield and Rogalski's study are based on returns for the intervals covering the opening hours and closing hours of the NYSE, respectively, their results suggest that the variance differential observed in previous studies may actually reflect the fundamental difference in the pattern of price movements during trading and non-trading periods. Comparing the weekend variance with the overnight variance, the authors find that the weekend variance is approximately twice the overnight variance. This further suggests that price variability is also non-constant during non-trading periods. The comparison test of within-week trading day variances, however, does not lead to the rejection of the hypothesis that trading day variance is constant.

Transactional data is also used in studies by Harris [69] and Wood, McInish and Ord [131]. Harris focuses on characterizing the weekly and intradaily patterns in return for all stocks listed on the NYSE for the fourteen months between December 1, 1981 and January 31, 1983. In this study, the intraday returns are measured over 15-minute intervals. Decomposing close-to-close returns into trading and non-trading returns, Harris finds that for large firms, the negative Monday close-to-close return accrues before the market opens, while for smaller firms most of it accrues during the trading on Monday. Further investigation of the 15-minute series of intradaily returns reveals that there are only significant differences among weekdays during the first 45 minutes of trading. Prices tend to drop on Monday mornings and they tend to rise on other weekday mornings. Lastly, evidence reveals the tendency of prices to rise on the last trade of the day, resulting in a U-shaped pattern of intraday variance.

Wood, McInish, and Ord [131] investigate the characteristics of transaction-by-transaction return index of the NYSE listed stocks for the six months from September 1971 through February 1972 and for the calendar year 1982. The results suggest that the process generating average market returns differs significantly over the trading day. The authors find that mean returns tend to be high in the earliest part of the day, especially in the first 30 minutes of trading, then increase sharply again at the end of the trading day. This concentration of high mean returns at the beginning and end of the trading day is consistent with the findings of Harris [69]. The results also reveal that the variability of returns differs significantly over the day. Similar to the pattern of intradaily returns, the standard deviation of returns exhibits a U-shaped pattern over the hours of the trading day, with the highest standard deviation reported for the earliest part of the day. High standard deviation observed at the market opening may reflect the impact of news accumulated overnight, while the high standard deviation at the end of the trading day could be due to the closings of positions by some traders (both in cash and futures markets) as well as the arrivals of information released during the later part of the afternoon.[10]

2.3 Patterns of Variance: Information Effect

Another explanation for variance differential over trading and non-trading periods is that volatility changes in response to the arrival and assimilation of information that is non-uniform across trading and non-trading hours. Grossman [63] has shown that information is collected as long as the expected gain from trading on that information exceeds that costs of producing that information. French and Roll [54] conduct an empirical analysis of information arrival on the reaction of traders and trading and non-trading time stock return variance. They consider three possible explanations for the observed variance pattern. First, high trading-time variance is caused by public information which is more likely to be observed during normal business hours. Public information is information that becomes known to all market participants at the same time that it begins to affect stock prices, for example, Supreme Court decisions, financial reports, and governmental reports. Second, high trading-time volatility is caused by private information which is more likely to affect prices when the exchanges are open. This should occur since private information affects prices through trading only; thus the production of private information may be more common when the exchanges are open.[11] The benefits of producing private information are larger during the opening hours of the exchanges when investors are able to trade on their private information. The authors also point out that even if the production rate of private information is constant, trades based on this type of information could lead to high trading-time variance. Private information which has been produced during the exchange closing hours cannot be acted upon until the exchanges are open. As a result, price reaction will not be apparent until the exchanges are open.[12] The third explanation for the observed variance differential is that pricing errors induced by noise trading leads to high trading-time variance. To the extent that daily pricing errors occur during trading hours, these errors may increase the variance of stock returns.

To test the three hypotheses, French and Roll [54] use daily close-to-close returns for all stocks listed on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) between 1963 and 1982 to calculate stock returns and variances for weekdays, weekends, holidays, and holiday weekends. The average hourly variance when the NYSE is open is found to be approximately 72 times the hourly variance when the exchange is closed during the weekends. Exchange holidays (the NYSE and AMEX were closed on Wednesdays during the second half of the 1968 due to a paperwork backlog) allow French and Roll to compare the exchange holiday variance with a normal daily variance. The public information hypothesis predicts that the variance will not be reduced by the exchange holidays in 1968 since the generation of public information should be a function of normal business hours and not of the exchange trading hours. According to the private information hypothesis, the variance will be reduced by the exchange holidays. Exchange holidays tend to reduce the value of private information which need to be acted upon before it becomes public. However, if the private information hypothesis is correct, then the reduction in variance should be temporary since some variance should be recovered on days immediately following exchange holidays. Equivalently, the variance on days following exchange holidays should be higher than normal. The trading noise hypothesis, on the other hand, predicts that the reduction of variance on exchange holidays will be permanent.

The estimated daily variance ratios for exchange holidays are found to be consistent with both the private information and the noise trading hypotheses. On average, the two-day exchange variance (Tuesday-close to Thursday-close) is only 14.5% higher than the variance for normal one-day returns. French and Roll [54] examine the relative importance of the information and noise trading hypotheses by considering the autocorrelation in stock returns. Under the trading noise hypothesis, returns should be autocorrelated due to pricing errors. If these pricing errors occur mainly during trading hours, they can represent a source of high trading time volatility. The authors point out that it is difficult to characterize short-run serial correlations without specific mispricing model. However, unless market prices are unrelated to the fundamental economic value of the stock, pricing errors (overshooting and undershooting) must be corrected in the long run. These corrections would tend to generate negative serial correlations. Neither public nor private information will generate observable autocorrelation as the variance of expected return is too small to cause observable serial correlation in realized returns.[13] The autocorrelation structure suggests that trading noise could have an effect on daily variance. However, further statistical analysis shows that even though approximately 4% to 12% of the daily variance may be explained by mispricing errors, these errors have a trivial effect on the difference between trading and non-trading variances. The overall results, therefore, lead French and Roll to conclude that the trading/non-trading time variance differential is caused by differences in the flow of information during the opening and closing hours of the major exchanges. For the sample of stock returns examined, small return variance over exchange holidays suggest that most of the information is private.

Recent theoretical studies also shed some light on the pattern of stock return volatility. Goldman and Sosin [60] examine the interaction between the process of information dissemination and specific market structure. Specifically, the authors are concerned with the speed and magnitude of price adjustments as information become publicly available and how the information dissemination process is affected by alternative market structures. Two market structures are examined, the continuous tatonnement process of the New York Stock Exchange and the relatively discontinuous trading process of the Paris Stock Exchange where each security is traded only a handful of times per day. They develop a model in which dissemination uncertainty arises because investors do not have the same information. In this model, information is disseminated through trading from the imformed investors to the rest of the market participants. When informed investors trade on their information, they must wait until the information is disseminated to the uninformed investors whose trade finally results in the final price change to full-information equilibrium level. However, if the dissemination process is expected to take too long (i.e., there is uncertainty about the dissemination speed) then some information will be ignored since the expected return from using it immediately does not cover the expected cost of informed investors' capital. Thus, it will not pay informed investors to impound all information in prices. As a result, prices will "undershoot" the full-information equilibrium prices. Goldman and Sosin also show that when there is added uncertainty for informed investors about how much information others possess, then price may "overshoot" the full-information level. This should occur since the uncertainty about the path of information will tend to induce larger speculative positions; hence, immediate price changes will cancel out the undershooting and lead to overshooting of prices. Goldman and Sosin then demonstrate that if overshooting is a dominant force in the market, the variance of price changes computed over relatively short intervals (e.g., daily) could vastly overstate the true underlying market variance. That is, if the measurement interval for returns is short enough, then only the initial overshooting shock and not the sum of the initial shock and subsequent corrections would be incorporated into the variance. Similarly, if undershooting predominates, then the use of short return intervals will understate the true variance. Finally, Goldman and Sosin's results imply that, other things being equal, continuity in trading will tend to increase the market volatility.

Kyle [89] develops a theoretical model with three types of traders in the markets: informed investors who trade on their private information, random liquidity traders who execute orders arriving randomly, and the specialist who learns from price and volume without attempting to acquire his/her own private information. In this model, the variance of returns over the entire trading interval reflects only the arrival rate of information while the variance of return within the trading interval also reflects trading activity of the random liquidity traders. The variance of returns is therefore due to both trading by informed and liquidity traders since uninformed traders who can only infer information from price and volume cannot distinguish between the two. The trading noise in this model is rational in the sense that the price established by the specialist is an unbiased estimate of the true price, conditional on his information set (i.e., observed price and volume constitute a noisy signal from trading by informed investors).[14] Moreover, this trading noise does not induce pricing errors. An implication of Kyle's model is that return variance is associated with trading volume. In a related work, Admati and Pfleiderer [2] present an extension of Kyle's model. In their model, Admati and Pfleiderer postulate the existence of two types of liquidity traders: the discretionary and the random liquidity traders. Both types of liquidity traders have no private information. However, unlike liquidity traders, discretionary liquidity traders possess some discretion on the timing of their trade. In addition, the informed traders in this model do not necessarily have perfect information. The equilibrium obtained in the model suggests that discretionary liquidity trading will be typically concentrated, and informed traders tend to trade more actively in periods with concentrated liquidity trading.[15] Informed traders also find it beneficial to acquire information in periods of concentrated liquidity trading. As trading by informed traders becomes more active, prices will be more informative during the period with high liquidity.

While Admati and Pfleiderer's theoretical results shed some light on the empirical finding regarding non-stationarity of intraday variance, they do not offer a complete explanation for the higher trading-time variance observed in earlier studies (e.g., French and Roll [54]). According to Admati and Pfleiderer's model, if liquidity trading volume is higher at the end of the day, then trading by informed traders will also tend to be concentrated at this time. As a result, prices at the end of the day will reflect more of the privately acquired information that will become public during the following non-trading period. However, as pointed out by Admati and Pfleiderer, this effect does not appear sufficient to account for the significant difference in trading/non-trading time variances reported by French and Roll [54].

Theoretical frameworks modeling stock trading behavior as developed by Kyle, Admati and Pfleiderer focus on information that is privately acquired.[16] Variance is associated with the trading reaction of informed investors and liquidity traders to each other (i.e., trade generates trade). However, there is substantial empirical evidence which suggests that stock return volatility is also significantly affected by the arrivals of public information. French, Schwart, and Staumbaugh [55] demonstrate that the ex ante risk premium on common stocks is positively related to the anticipated volatility of returns. Bower and Bower [18] present evidence that the stock residual variances around the time of dividend-omission announcements are twice as large as the variances during non-event periods. Beaver [9], Patell and Wolfson [106], Christie [26], and Kalay and Lowenstein [83] all report that stock returns are more volatile around regularly scheduled announcements. Moreover, if the news announcements are unanticipated, the uncertainty around the events can be even greater. Recently, Brown, Harlow, and Tinic [21] developed the uncertain information hypothesis as a means to explain the response of rational, risk-averse investors to the arrival of unanticipated information. The hypothesis predicts that following news of a dramatic financial event, both the risk and expected return of the affected stocks increase systematically. While capital market rationality assumes that investors learn to make correct inferences about the impact of new information on the future distribution of returns (i.e., the formation of noisy rational expectation), it does not imply that prices react instantaneously to information. This should be the case since investors often set stock prices before they are completely certain about the full ramifications of a dramatic financial event. As a result, the short-run price movements can exhibit increased volatility while the uncertainty about the full impact of the news is being resolved. The authors use over 9000 market-wide and firm-specific events to test the uncertain information hypothesis. Their results support the view that the market reacts to uncertain information in an efficient, though not instantaneous manner.[17] In addition, the study presents evidence that unanticipated events tend to induce increases in volatility and expected returns.

In a recent study, Ross [117] shows that in an arbitrage-free economy the volatility of prices is directly related to the rate of flow of information to the market. In Ross' arbitrage model, the volatility and information rate are shown to be identical (i.e., if the volatility of prices is not equal to the rate at which information arrives then arbitrage is possible). This result is independent of the asset pricing model which is used. However, the major implication of this arbitrage analysis for the trading/non-trading time effect is that if prices are more volatile when markets are open for trading then more information must be released when markets are open than when they are closed. Ross' analysis, therefore, is consistent with previously reported empirical evidence (e.g., French and Roll [54]) which indicates that variance is higher during trading than during non-trading periods and that the observed variance differential is due to uneven flow of information through time.

2.4 Patterns of Variance: International Markets

The present trend towards globally integrated financial markets has led to greater interest in research into the characteristics of distributional parameters for assets which are traded internationally. The effect of information arrival on trading and non-trading time variances for stocks with international listings is examined in recent empirical studies. Barclay et al. [6] examine the effect of information and expanded trading hours on the return variance of U.S. stocks listed on the NYSE and the Tokyo Stock Exchange (TSE). For a stock that is traded on multiple markets, liquidity traders will concentrate their trading in the market with the lowest transaction costs. For U.S. stocks traded in the U.S. and Japan, the transaction costs of liquidity traders should be lowest on the domestic NYSE. To the extent that informed investors tend to trade when trading by liquidity traders is concentrated, return variance measured during the NYSE trading hours should be positively associated with the higher trading volume on the NYSE. The authors report that the average volume of U.S. stocks with secondary listing in Japan on the NYSE accounts for approximately 92% of the total trading volume in 1986. Comparing the daily (open-to-close) and 24-hour (close-to-close) variances of U.S. dual-listed stocks with those of matched NYSE-listed stocks, the authors find no significant difference in the ratios of within-day to 24-hour variance between the two groups of stocks. Secondary listing of U.S. stocks in Japan does not appear to increase stock return variance.[18] It should be pointed out, however, that while the results suggest that the magnitude of the total variance may not change, the distribution of return variance can be affected by the trading on the TSE. Since news with significant impact on stocks is often released after the closing of the NYSE, it is possible that a non-trivial fraction of the overnight return variance of the dual-listed stocks is actually caused by investors' trading on the TSE in reaction to the after-hours new releases in the U.S. For some information whose value declines rapidly with time, some investors (e.g., non-liquidity traders) may find it beneficial to trade on the TSE despite higher liquidity and lower average transaction costs on the NYSE. Since the authors estimate daily return variances from U.S. prices only, they do not explicitly consider the sensitivity of the difference between trading and non-trading time variances (estimation of trading and non-trading time variances should be based on opening and closing prices in various international markets) to trading on foreign markets. While their results suggest that substantial trading volume is required for prices to reflect private information, they are also consistent with the view that variance is caused by increased public information released during the hours of the primary exchange.

In a similar study, Makhija and Nachtman [93] assess the effect of expanded trading time on the daily close-to-close return variances of 81 stocks cross-listed on the New York Stock Exchange and the London Stock Exchange (LSE) during 1969-1982. Contrary to the findings on the impact of TSE listing on the 24-hour variance of NYSE-TSE cross-listed stocks by Barclay et al. [6], the authors report a significant increase in the 24-hour (U.S. close-to-close) return variance of NYSE-LSE cross-listed stocks following the listing on the LSE. They conclude that the opportunity to trade on the LSE induces investors to acquire additional information. Viewing information as a store of volatility, greater production of information leads to an increase in return variance after cross-listings. In sum, while the studies by Makhija and Nachtman [93] and by Barclay et al. [6] have not fully considered the time pattern of variance across various trading and non-trading periods in international markets (i.e., trading and non-trading time variances that are based on opening and closing prices from different markets), they provide evidence which suggests that the effect of information and trading in international stock markets on stock return variance may differ for various foreign markets in which the stocks are listed.[19]

The impact of information arrival on price movements has also been investigated for the foreign exchange markets. World-wide foreign exchange trading takes place on a 24-hour basis. In two related studies, Ito and Roley [78, 79] examine the impact of news announcements on the Yen/Dollar spot rate movements. In the first study [78], the authors document the characteristics of Yen/Dollar movements in four intraday disaggregated segments from 1908 through 1985. These segments are (1) open to close (New York), (2) New York-close to Tokyo-open, (3) open to close (Tokyo), and (4) Tokyo-close to New York open. The results indicate that the New York market was generally more volatile, perhaps reflecting more relevant news. Among the economic announcements considered, Ito and Roley find that unanticipated changes in the U.S. money supply had the most consistent effects, especially prior to 1984. Positive "surprises" were found to result in dollar appreciation. Other U.S. announcements had effects only in the post-February 1984 period, which could reflect the change in emphasis by the Federal Reserve Bank and traders from money supply to economic activity. For Japanese economic announcements, only industrial production news exhibit impacts on the rate movements. In a related study, Ito and Roley [79] analyze the movements of the Yen/Dollar spot rate in the same four segments from 1980-1986. In this analysis, they focus on testing for the information content of intraday Yen/Dollar rate movements in terms of their impacts on the movements of the S&P 500 Index and the Japanese Nikkei-Dow 225 Index prices. The results provide evidence that Yen/Dollar movements of less than one day contain relevant information. The authors conclude that the rate movements are not simply due to noise-induced trading.

2.5 Patterns of Variance: Financial and Commodity Futures Markets

Significant patterns in the distributions of return and variance have also been documented in futures markets. Chiang and Tapley [24] investigate the day-of-the-week effect in the futures markets using the daily data for commodity and financial futures listed on the Chicago Board of Trade over the period 1972 through 1980. Regression analysis is used to test for day-of-the-week effect in price change distribution for various futures contracts. The results indicate the existence of day-of-the-week effect in the commodity futures markets. Similar to the patterns in common stock returns reported by Gibbons and Hess [58] and French [53], the market (a composite of CBOT contracts) and grains average futures price change peak on Wednesday, have their second high on Friday, and are negative on Monday. However, for the Treasury futures, the highest average price change occurs on Friday with a second high on Tuesday. In general, the results show that the pattern and magnitude of the day-of-the-week effect are particular to the type of futures contracts. This suggests that the price change patterns are influenced by differences in information assimilation as well as in institutional arrangements.

Dyl and Maberly [40] investigate the daily distribution of price changes for the S&P 500 Stock Index Futures using the daily opening and closing prices from June 1, 1982 through May 17, 1985. Comparing average price changes over trading and non-trading periods, the authors find a weekend effect (i.e., negative Friday-close to Monday-open) similar to that reported by Rogalski [112] for the stock returns.[20] Comparison of daily price variances reveals that the average trading time variance is significantly higher than the non-trading time variance. Moreover, they find that this variance differential also persists for each day of the week.

Jordan et al. [81] examine the information and trading time effects on intraday variability of soybean futures prices. They use transactional data to characterize the pattern of soybean futures price change variances across 45-minute intraday intervals for the period January 1978 through October 1984. The results indicate that the price change variance of soybean futures is more than 30% higher in the first and last 45 minutes of trading than during any other periods of the trading day. The observed intraday variance pattern is similar to the U-shaped pattern of stock return variance reported by Harris [69]. The authors hypothesize that high variance at the start of trading day is due to the regular arrival and assimilation of public information relevant to soybean prices. The information hypothesis predicts that the average variance associated with the first 45 minutes of trading should be greater on days following the report release dates than other days. This prediction is supported by the results which reveal that the variance associated with the first 45 minutes of trading is on average 10% higher on days following report releases than on other days of the week. The higher variance during the last 45 minutes of trading is less readily attributable to information effect since there are no public information announcements prior to or during this interval. The authors postulate that concentrated trading by day traders to close their positions at the end of the day could lead to the observed increase in variance during the last 45 minutes of trading. However, further research is required to explain completely the observed U-shaped pattern of price change variance in the soybean futures market.

In a recent study, Lauterbach and Monroe [92] also use transactional data to investigate nonstationarity in the variance pattern for gold futures contracts traded on the Chicago Merchantile Exchange (CME). Similar to the intraday variance pattern for the soybean futures reported by Jordan et al. [81], the intraday variance of gold futures also exhibits a U-shaped pattern over trading hours of the CME. In addition, the results of the study show that the trading time variance is significantly higher than the non-trading time variance for the gold futures. While the authors discuss implications of information flow and noise trading, they do not include any empirical tests of the information effect in their study.

Nonstationarity in the pattern of variance has also been documented for some foreign assets. In a recent paper, Geman, Savanayana, and Schneeweis [57] provide empirical evidence indicating that price change variances for the French Long-Term Bond futures contracts traded on the MATIF differ between trading (daytime) and non-trading (overnight) periods. In contrast to results for U.S. markets, the results suggest that reported variances are often greater during non-trading periods of the French markets. Several explanations may explain the differential in results relative to the U.S. markets. Information flows during trading hours affecting French bond markets may be of smaller magnitude than those generated during a U.S. and Japanese trading session which conincides with the French non-trading session. However, results also indicate that the differential in trading and non-trading time variances in the French bond market may be decreasing. The authors suggest that, assuming similar information releases between markets, the decrease in variance differentials may reflect increasing liquidity and falling transaction costs in the French market.

While extensive analysis of information and trading/non-trading time effects have taken place for futures contracts traded in the U.S. markets, relatively little research in the same area exists for futures contracts which have multiple listings in international markets. Marsh and Webb [95] examine the effects of trading continuity and market structures on the variability of soybean futures traded on the Chicago Board of Trade (CBOT) and the Tokyo Grain Exchange. Specifically, they conduct tests of the hypothesis that in the face of uncertainty about the dissemination of information, volatility in a continuous trading environment will be higher than volatility in a discontinuous trading (see also Goldman and Sosin [60] for the theoretical development of this hypothesis). The CBOT and the Tokyo Grain Exchange differ markedly in their market structures. While the CBOT trading can be characterized as a nearly continuous series of English auctions, the trading at the Tokyo Grain Exchange is based on a single-price auction method which closely resembles the Walrasian tatonnement process. In addition, the two exchanges offer two different sets of delivery months for soybean futures contracts. Testing for differences between variances of comparable maturity soybean contracts on the two exchanges, the authors find that the average price change variance for the Tokyo Grain Exchange soybean contracts is higher than that of the corresponding CBOT contracts. The authors conclude that their results are inconsistent with the prediction of Goldman and Sosin's hypothesis since the discontinuity of trading on the Tokyo Grain Exchange appears to be associated with higher variance, not vice versa. Though Marsh and Webb`s results suggest that variance differential between the two markets is due to differences in market structures, their analysis does not explicitly consider the potential effects of relative information flows in the two markets which could contribute to the observed difference in variances.[21]

In a recent paper, Hill, Schneeweis, and Yau [72] investigate the risk patterns of the internationally traded U.S. Treasury bond and Eurodollar futures contracts. Using daily prices of the nearby September contract in July and August of 1986, 1987, and 1988, the authors provide evidence that the trading and non-trading time estimates of price change variance for the U.S. Treasury bond and Eurodollar futures may differ depending on the time period within the 24-hour cycle and the international market in which the contract is traded. They conclude that their results are consistent with the view that differences in variances measured over various periods during a 24-hour cycle are mainly due to information, liquidity and transaction costs effects.

The literature reviewed so far indicates that risk as measured by variance of asset return or price can be nonstationary across time periods within the 24-hour day as well as over different days of the week. A summary of studies on the nonstationarity of estimated variances is presented in Table 2 (p. 38). While existing literature offers little empirical evidence that support either the calendar time or transaction time hypothesis, a growing number of studies have provided evidence which suggests that trading/non-trading time effects in intraday and interday variance patterns is closely related to the process of information arrival through time. In view of the trend towards closer linkages among the world's financial markets; it is important to gain a better understanding of the risk characteristics of internationally traded assets, and how they are affected by an expanded information environment which includes domestic as well as foreign information. In this study, an analysis of the trading/non-trading time and information effects on the intraday and interday variance patterns of the U.S. Treasury bond and Eurodollar futures is undertaken.[18] The data, methodology and testable hypotheses for the analysis are discussed in the next Chapter.

TABLE 2

Summary of Research: Nonstationarity of Return Variance.

U.S. MARKETS

STOCKS

Fama [45]	Results show that the weekend and holiday (close-to-close) variance is only 22% higher than the weekday variance for 11 Dow Jones stocks.
French [53]	The weekend to average within week (close-to-close) variance ratio of 1.42 is reported for S&P 500 (1953-1977).
Keim and Stambaugh [86]	Analyses and results similar to those found in French [53] are performed with an expanded data set (1928-1982).
Oldfield and Rogalski [105]	Based on opening and closing prices for 5 NYSE stocks (1974-1977), trading time variance is found to be higher than the non-trading time weekend variance. Thus, results suggest that variance differentials reported in Fama and French reflect the fundamental difference in the pattern of price movements during trading and non-trading periods.
Harris [69]	Analysis of weekly and intradaily return patterns for all NYSE stocks (12/1/81 - 01/31/83). Returns are measured over 15 minute intervals. Returns appear to differ among weekdays only during the first 45 minutes of trading only. Also, results reveal a U-shaped pattern of the intraday variance.
Wood et al. [131]	Analyses similar to those in Harris [69] are performed using data from Sept. 1971 to Feb. 1972 and the year of 1982. The standard deviation also exhibits a U-shaped pattern over the trading day.

Continued, next page

Table 2 (continued)

French and Roll [54]	Based on daily close-to-close returns for all NYSE stocks (1963-1982), differential between exchange holiday and one-day variances is due to differences in information flow during the trading and non-trading hours of the exchange.
Brown et al. [21]	Tests of the uncertain information hypothesis. The results show that short-run price movements can exhibit increased volatility while the uncertainty about the full impact of news release is being resolved.
Kyle [89]	Theoretical model shows the variance during trading period is due to trading by informed and uninformed traders. A major implication is that variance is associated with trading volume.
Admati and Pfleiderer [2]	An extension of Kyle's model implies that informed investors tend to trade more actively in periods with concentrated liquidity trading at end of trading day. But is this effect sufficient to account for the significance difference between reported trading/non-trading time variances?
Goldman and Sosin [60]	A theoretical analysis of the interaction between information dissemination and specific market structure.The analysis suggests that continuity in trading will tend to increase the market volatility.
Ross [117]	Using a model of an arbitrage-free economy, Ross shows that the volatility of asset prices is directly related to information flow. This implication is consistent with conclusions reached by French and Roll [51], among others.

Continued, next page

Table 2 (continued)

FUTURES	
Chiang and Tapeley [24]	Based on daily settlement prices of commodity and financial futures listed on the CBOT (1972-1980),the day-of-the-week effect are particular to the type of futures contracts.
Dyl and Maberly [40]	Based on daily opening and closing prices of S&P 500 futures (1982-1985), the trading time variance is significantly higher than the non-trading time variance on all weekdays.
Jordan et al. [81]	A U-shaped pattern of intraday variance is reported for U.S. soybean futures (1978-84). Variance associated with the first 45 minutes of trading is higher on days following relevant report releases than on other days of the week.
Lauterbach and Monroe [92]	A U-shaped pattern of variance is observed over the trading hours of the CME. Trading time variance is greater than non-trading time variance for the gold futures.

Continued, next page

Table 2 (continued)

INTERNATIONAL MARKETS

STOCKS

Barclay et al. [6]	Analysis of the information effect and extended trading hours for U.S. NYSE-TSE listed stocks. Higher NYSE variance is associated with higher trading volume or public information releases in the U.S.
Makhija and Nachtman [93]	Contrary to results reported by Barclay et al. [6], significant increase in the 24-hour variance of the NYSE-LSE listed stocks following the listing on LSE is documented.

FUTURES

Marsh and Webb [95]	The price change variance for the soybean futures traded in Japan is higher than that of the contracts traded in the U.S. However, the analysis does not consider information flows in the two markets.
Geman et al. [57]	In contrast to results for U.S. markets, variance of the French Long-term Bond futures are often greater during non-trading periods of the French markets. Higher non-trading time variance may be due to the magnitude of information flows during the U.S. and Japanese trading session which coincide with the French non-trading hours.
Hill et al. [72]	An investigation of the trading/non-trading time price change variance for the U.S. Treasury bond futures and Eurodollar futures. Variance differentials are likely to be due to differences in information flows, transaction costs, and liquidity between markets and various trading, non-trading periods.

CHAPTER 3

DATA, METHODOLOGY, AND TESTABLE HYPOTHESES

3.1 General Data Description

The investigation of trading/non-trading time and information effects in the volatility pattterns for the U.S. Treasury bond futures and Eurodollar futures contracts is based on daily data consisting of opening, high, low, and closing prices of the two futures contracts from the markets in which the contracts are actively traded for the period 1986 through 1988 (1987 throuhg 1988 in the case of Eurodollar futures). For the U.S. Treasury bond futures, daily prices are obtained from the Chicago Board of Trade (CBOT) and the London International Financial Futures Exchange (LIFFE). For Eurodollar futures, daily prices are obtained from the Chicago Mercantile Exchange (CME) and LIFFE.

3.1.1 U.S. Treasury Bond Futures Contracts

The U.S. Treasury bond futures is one of the most successful futures contracts in the financial futures market. The contract presently accounts for more than half of the total volume of futures and options contracts traded on the CBOT. The U.S. Treasury bond futures are used in a wide range of investment strategies. The principal usage of the contracts, however, has been in the area of risk minimization and asset risk/return management (see, for example, Yau, Savanayana, and Schneeweis [132, 133] on alternative risk management models using interest rate futures). The contract calls for the delivery of $100,000 worth of Treasury bonds having at least 15 years remaining until maturity or their first call date. The U.S. Treasury bond futures contracts are traded for delivery in March, June, September, and December. During the period examined the contracts were traded in the U.S. (CBOT), United Kingdom (LIFFE), Singapore (SIMEX), and Australia (Sidney Futures Exchange). While the U.S. Treasury bond futures can also be traded during the closing hours of these major exchanges (i.e., over-the-counter trading), it is assumed that the effects of transaction costs and liquidity on price movements during these times are such that they may be classified as non-trading periods. Starting on April 30, 1987 the CBOT U.S. Treasury bond futures contracts are also traded in the evening sessions (6 P.M.-9 P.M., Monday through Thursday). Since September 17, 1987 the evening trading has been extended to 9.30 P.M. and also to include the Sunday night session.

3.1.2 Eurodollar Futures Contracts

Eurodollar futures is a major futures contract on short-term interest rates (3-month maturity). The Eurodollar futures contract was the first to be fulfilled by cash settlement rather than by actual delivery of the underlying asset. Eurodollar deposits are non-transferable deposits held in banks outside the U.S. With the contract size of $1,000,000, the settlement of a contract involves a cash payment based on the measure of Eurodollar rates established by the International Monetary Market-IMM of the Chicago Mercantile Exchange (CME). Similar to the U.S. Treasury bond futures, Eurodollar futures contracts represent an important class of investment tools widely used in risk management. The Eurodollar futures contracts are traded for delivery in March, June, September,and December. During the period of analysis, the contracts were traded in the U.S. (IMM of CME), United Kingdom (LIFFE), and Singapore (SIMEX). Similar to the non-trading times for the U.S. Treasury Bond futures, it is assumed that time periods during which the three major exchanges are closed can be classified as non-trading periods for the Eurodollar futures.

3.2 Methodology and Testable Hypotheses

3.2.1 Estimation of Risk

A most common measure of risk is the variance of the probability distribution of the return on assets. Variance measures the dispersion of possible returns around the return expected at the end of the holding period. In the mean-variance valuation framework, risk-averse investors will prefer the investment with minimum risk or variance over alternative investments with equal expected returns but greater return variance.[23] While other risk measures are also used in financial research, variance of the return distribution is the most appropriate measure for the investigation of the pattern of risk for the U.S. Treasury bond futures and Eurodollar futures.

Another measure of risk that is extensively used in the finance literature is the asset beta. Beta measures the systematic risk of an asset that arises from the covariation of the asset's returns with the returns on the market as a whole. Beta of the U.S. Treasury bond futures and Eurodollar futures could be derived by considering the covariation of the return on the contracts with the returns on a "market" futures contract (see Duffie [39] for a theoretical derivation of the beta for futures contracts and the assumptions regarding the existence of a "market" contract in the framework of the Sharpe/Lintner/Mossin Capital Asset Pricing Model). Beta of the futures contracts, however, is not considered for the following reasons. First, beta is the appropriate risk measure when investment strategies under consideration are based on fully diversified portfolios. Strategies which require the inclusion of the U.S. Treasury bond or Eurodollar futures (e.g., risk minimization) do not always entail the construction of a well diversified portfolio. For a portfolio that is not well diversified, variance of the portfolio return is a more appropriate measure of the total risk of the portfolio. Second, the principal uses of interest rate futures are for risk minimization and risk/return management strategies (see Yau, Savanayana, and Schneeweis [132, 133]). These strategies are based on investment models (e.g., minimum risk hedging and Markowitz-based mean/variance optimization) which require variances of cash and futures as input parameters. Therefore, return variances of U.S. Treasury bond futures and Eurodollar futures are most relevant to investors who use these popular investment strategies. Lastly, the calculation of the futures betas would require that "market" futures contract be identified. While an existing index futures such as the S&P 500 stock index futures might be used as a proxy of the "market" contract, it would only be an appropriate proxy for the calculation of beta for futures contracts traded primarily in the U.S. markets. Since the U.S. Treasury bond futures and Eurodollar futures contracts are also traded in Europe and Far East, it is difficult to identify a futures contract traded in the same international markets as those for the U.S. Treasury bond futures and Eurodollar futures that might serve as a proper proxy for the "market" contract.

Other surrogates of asset risk that have been considered in financial research include semivariance, sevideviation, and semi-interquartile range. The semivariance and semideviation are usually calculated from only disappointingly low returns to measure the chance of loss associated with the left-hand tail of a probability distribution. The semi-quartile range is equal to half the difference between te 0.75 and 0.25 fractiles of the cumulative probability distribution. While these three surrogates may serve as alternatives to the return variance, it has been shown that they are highly correlated with the return variance when used as measures of asset risk (Cooley, Roenfeldt, and Modani [30]). As a result, only the return variance are used as the measure of risk in this study.

Since the primary objective of this study is to investigate the pattern of variance over trading and non-trading periods, return on the futures contract are based on either close-to-open or open-to-close daily prices depending on the day of week and the time of the day (i.e., trading and non-trading sessions of markets in which the U.S. Treasury Bond and Eurodollar futures are traded). In analyses involving spot assets, investment return is usually measured as the relative change in total value, that is, the total income consisting of price appreciation and income divided by the initial investment. For financial futures, a number of methods for measuring return have been proposed. Black [13] suggests that the return on a futures position should be measured by the simple price change ($P_{t+1} - P_t$) since there is no initial investment involved in futures trading as the Treasury bills can be used for initial margin. Moreover, Hill and Schneeweis [71] point out that many investors may view their investment payoffs in terms of the total monetary change in wealth rather than the percentage return. Thus, for investors who place the emphasis on the relative dollar change of their wealth, the price change can be regarded as the most appropriate measure of investment return. Alternatively, return on a futures position may also be measured as the percentage change in futures prices, $(FP_{t+1} - FP_t)/FP_t$. For futures contracts requiring only a margin deposit, a percentage change in value may offer an accurate representation of investment return. With only margin deposit representing initial investment, the return on a futures position can be expressed as $(FP_{t+1} - FP_t)/M_t$ if M_t, the margin, is in cash or $[(FP_{t+1} - FP_t) + M_t * r_t]/M_t$ if the margin is in the form of Treasury bills where r_t is the rate of return on the Treasury bills in period t to t+1. It should also be noted that not all investors face the same margin requirements.[24] For comparison purpose, percentage price change (discrete and continous compounding) is used in this study.

3.2.2 Variance Estimators

Two alternative variance estimators are used in this study. The descriptions of these estimators can be summarized as follows:

$$\text{Let } R_{ij} = \ln (FP_e / FP_b)_{ij} = U_{ij} + E_{ij}$$

where: $j = 1,\ldots,N$ observations in session i,
$i = 1,\ldots,M$ sessions (trading or non-trading)
R_{ij} = return j on futures measured in session i,
FP_b = the price at the beginning of session i,

FP_e = the price at the end of session i,
U_i = The mean return of session i, not necessarily known or assumed equal,
E_{ij} = Random component, i.i.d. with zero mean.

The most common estimator of variance is the maximum likelihood estimator of the variance of a normal distribution. This estimator is calculated as follows:[26]

$$S^2_i = [\sum_j (R_{ij} - \bar{R}_i)^2]/N_i$$

where R_{ij} = return j measured over session i,
= ln(ending $price_i$ / beginning $price_i$) or (ending $price_i$ - beginning $price_i$) - 1,
$\bar{R}_i = \sum_j R_{ij}/N_i$,
N_i = number of returns in session i.

Standard F-statistics will be used to determined the statistical significance of the differentials between variances estimated for various trading and non-trading periods.

As an alternative to the estimation of variance that is obtained from the opening and closing prices, Parkinson [107] derives a variance estimator that is based on high and low prices. The Parkinson estimator can be expressed as follows:

$$P_i = (.361/N_i)\sum_j d_{ij}^2$$

where d_{ij} = ln(high $price_j$ /low $price_j$) in session i,
N_i = number of observations in session i.

Since high and low prices are presumably obtained through continuous monitoring of asset price movements, they should contain more information than the opening and closing prices, which may be viewed as merely "snap shots" of the price process. The Parkinson estimator is more efficient than the classical estimator S^2 (Efficiency of an estimator Z is defined as Eff(Z)= (Variance(S^2)/Variance(Z)). In this study, the Parkinson estimator is also used to estimate the trading-time variance for the two futures contracts.[27]

3.3.3 Estimation of Variance: Trading and Non-Trading Sessions

To examine the patterns of volatility for the U.S. Treasury bond futures and Eurodollar futures, variances are estimated for trading and non-trading periods using daily opening, closing, high, and low prices from the CBOT, LIFFE for the U.S. Treasury bond futures, and the CME, LIFFE, and SIMEX for the Eurodollar futures. The periods of analysis for the U.S. Treasury bond futures and Eurodollar futures are January 1986 through November 1988, and January 1987 through November 1988, respectively. Since the nearby contract is generally the most actively traded until the beginning of the delivery month, daily prices of the nearby contracts (starting with the March 1986 contract and ending with December 1988 contract with the roll-over on the first day of the delivery month) is used to estimate the return variances for various trading and non-trading sessions. The exchange hours of the U.S. Treasury bond Futures and Eurodollar futures and the trading and non-trading sessions to be examined in the analysis of trading/non-trading time and information effects are presented in Table 3 (p. 51) and Table 4 (p. 52), respectively.

TABLE 3

Trading Hours of the U.S. Treasury Bond Futures and Eurodollar Futures Contracts.

U.S. Treasury Bond Futures Markets Trading Hours

CBOT		LIFFE
8 A.M.-2 P.M.	6 P.M.-9.30 P.M.	2.15 A.M.-10.10 A.M.

Eurodollar Futures Markets Trading hours

IMM (CME)	SIMEX	LIFFE
7.20 A.M.-2 P.M.	6.30 P.M.-2.20 A.M.	2.30 A.M.-10 A.M.

Notes:

1. The CBOT opened night trading session (Mon.-Thurs.) on April 30, 1987. On September 17, 1987 Sunday night trading commenced and all night trading sessions were extended from 9 P.M.to 9.30 P.M.
2. The hours presented in this table are in effect during the period of Central Daylight Saving Time. During the period of Central Standard Time, the evening trading on the CBOT is from 5 p.m. to 8.30 p.m.

TABLE 4

Trading and Non-Trading Sessions of the U.S. Treasury Bond Futures and Eurodollar Futures Contracts.

U.S. Treasury Bond Futures

Pre April 30, 1987

1. 2.15 A.M.-8 A.M. (Open LIFFE to Open CBOT)
2. 8 A.M.-10.10 A.M. (Open CBOT to Close LIFFE)
3. 10.10 A.M.-2 P.M. (Close LIFFE to Close CBOT)
4. 2 P.M.-2.15 A.M. (Close CBOT to Open LIFFE-next day)*

Trading sessions: 1,2,3. Non-trading session: 4.

Post April 30, 1987

1. 2.15 A.M.-8 A.M. (Open LIFFE to Open CBOT)
2. 8 A.M.-10.10 A.M. (Open CBOT to Close LIFFE)
3. 10.10 A.M.-2 P.M. (Close LIFFE to Close CBOT)
4. 2 P.M.-6 P.M.* (Close CBOT to Open CBOT-evening session)
5. 6 P.M.-9 P.M. (Open CBOT-evening to Close CBOT-evening)
6. 9 P.M-2.15 A.M. (Close CBOT to Open LIFFE-next day)

Trading sessions: 1,2,3,5. Non-trading sessions: 4 and 6.

Eurodollar Futures Trading

January 1986 to December 1988

1. 2.30 A.M.-7.20 A.M. (Open LIFFE to Open CME)
2. 7.20 A.M.-10 A.M. (Open CME to Close LIFFE)
3. 10 A.M.-2 P.M. (Close LIFFE to Close CME)
4. 2 P.M.-6.30 P.M. (Close CME to Open SIMEX)
5. 6.30 P.M.-2.30 A.M. (Open SIMEX to Open LIFFE-next day)

Trading periods: 1,2,3,5. Non-trading period: 4.

* Prior to Sept. 17, 1987 when Sunday evening trading begun, session 4 is from 2 P.M. Friday-close to 2.15 A.M. Monday-Open LIFFE for weekends.

The sessions presented in Table 4 span the 24-hour cycle of an international trading day. The trading hours in various markets may overlap (e.g., trading hours of the U.S. Treasury bond futures at CBOT overlap with those at LIFFE and trading hours of the Eurodollar futures at CME overlap with those at LIFFE). These overlapping time periods provide arbitrage opportunities between markets (see Emmanuel, Finn, and Lane [42] for an analysis of such arbitrage opportunities). The arbitrage relationships ensure that the prices in two open markets are within the boundaries of transaction costs. It should also be noted that the U.S. Treasury bond futures contracts are also traded in Sidney, Australia and Singapore (SIMEX). However, the trading of the contracts in these markets have not been active. In addition, the hours presented may vary during times of the year due to changes in daylight savings time, etc.

To ascertain the overall pattern of risk, return variances for various trading and non-trading sessions are estimated. Due to the addition of the evening trading session on the CBOT in April of 1987, the analysis is performed separately for the time periods: (1) January 1986 to April 1987 and (2) May 1987 to November 1988. The division of the sample period into these two subperiods is necessary to keep the number of trading and non-trading sessions constant in each subperiod. There are 4 trading sessions for the Treasury bond futures at the CBOT prior to April 30, 1987 while there are 5 trading sessions at the CBOT after that date. Moreover, separate analyses using the the U.S. Treasury bond futures prices before and after April of 1987 permits the assessment of the impact of CBOT evening trading session on the variance pattern of the U.S. Treasury bond futures prices.

In order to avoid potential problems associated with thin trading in distant contracts, only daily prices of the nearby contracts is used.[28] Since the "maturity effect" may exist in the patterns of variances, the analysis of trading/non-trading time variance differentials are repeated using daily prices of the nearby contracts during 1, 2, and 3 months before delivery month with prices in the delivery month excluded (see Milonas and Vora [99]). In addition, the analysis is undertaken on the contract month basis. The partition of the sample by contract months accounts for possible differences in the patterns of price movements for futures contracts expiring at different times of the year.

The analysis is performed separately for the two futures contracts for the described subsamples.[29] Alternative variance estimators of individual trading and non-trading time intervals are calculated and compared. The null hypotheses tested can be stated as follows:

For U.S. Treasury bond futures:

$H1_0$: $S^2_1 = S^2_2 = S^2_3 = S^2_4$ (pre-April, 1987)

$H1_0: S^2_1 = S^2_2 = S^2_3 = S^2_4 = S^2_5 = S^2_6$ (post-April, 1987)

For Eurodollar futures:

$H1_0: S^2_1 = S^2_2 = S^2_3 = S^2_4 = S^2_5$ (1987-1988)

where S^2_i = estimated variance of session i (trading or non-trading session) during the day.

The hypothesis of equal variances is also tested using hourly variances (estimated variances divided by the number of hours in the corresponding sessions). The calculation of hourly variances assumes that (1) price changes are intertemporally uncorrelated, and (2) there are only two uniform regimes, trading and non-trading hours; price changes are independently identically distributed within these regimes but they may have different variances.[30] Hourly variance comparison allows the test of calendar time, transaction time, and information effect hypotheses to be performed.

For U.S. Treasury bond futures:

$H2_0: (S^2_1/h_1)=(S^2_2/h_2)=(S^2_3/h_3)=(S^2_4/h_4)$ (pre-April, 1987)

$H2_0: (S^2_1/h_1)=(S^2_2/h_2)=(S^2_3/h_3)=(S^2_4/h_4)=(S^2_5/h_5)=(S^2_6/h_6)$ (post-April, 1987)

For Eurodollar futures:

$H2_0: (S^2_1/h_1)=(S^2_2/h_2)=(S^2_3/h_3)=(S^2_4/h_4)=(S^2_5/h_5)$ (1987-1988)

where h_i = the number of hours in session i.

If the null hypothesis that hourly variances are equal across trading and non-trading periods cannot be rejected then the test results would be consistent with the calendar time hypothesis which posits that variance per hour will be the same for all periods since the pricing process operates continuously on the calendar time basis. However, the rejection of the null hypothesis would be consistent with both the transaction time and information/trading time hypotheses.

To further distinguish between these two hypotheses, the transaction time hypothesis prediction that hourly variances over different trading times are equal as predicted are tested. The rejection of equal trading time variances would be consistent with the alternative hypothesis that the distribution of variances is mainly a function of information flow which need not be uniform across trading and non-trading periods.[31]

For U.S. Treasury bond futures:

$H3_0: (S^2_1/h_1)=(S^2_2/h_2)=(S^2_3/h_3)$ (pre-April, 1987)

$H3_0: (S^2_1/h_1)=(S^2_2/h_2)=(S^2_3/h_3)=(S^2_5/h_5)$ (post-April, 1987)

For Eurodollar futures:

$H3_0: (S^2_1/h^1)=(S^2_2/h_2)=(S^2_3/h_3)=(S^2_5/h_5)$ (1987-1988)

3.3.4 <u>Estimation of Variance: Interday Pattern</u>

Tests of equal variances between trading and non-trading sessions (listed in Table 4, p. 49) are also conducted separately for each day of the week using the daily prices of nearby contracts.[32] To the extent that variances may vary across times of the day, test results will show whether intraday nonstationarity of return variance exists on all weekdays. The null hypothesis can be stated as follows: For U.S. Treasury bond futures and Eurodollar futures;

$H4_0$: Trading time and non-trading time variances are equal on all days of the week (Monday to Friday).

3.3.5 Effect of Weekends and Holidays

Exchange holidays can affect the patterns of variances since investors must wait longer than usual to execute their trades in the next trading session of their local or overseas markets (e.g., Barclay et al. [6] and Geman et al.[57]). Likewise, weekends can affect the estimation of variance since they represent relatively long non-trading periods (Phillips-Patrick and Schneeweis [109]). The impact of including holidays and weekends in the trading/non-trading time variance analysis is examined in this study. The null hypothesis can be stated as follows:

$H5_0$: Exchange holdays and weekends have no impact on the patterns of trading and non-trading time variances.

3.3.6 Effect of Information Releases

It is anticipated that results of the analysis described in previous section will show that estimated variances of the U.S. Treasury bond futures and Eurodollar futures differ both between trading and non-trading periods as well as between trading periods on different markets. Such results will be consistent with the view that asset price changes in response to new information flow which may be uneven across time periods. To further examine the relationship between the variance patterns of U.S. Treasury bond futures and Eurodollar futures and information arrival process, the impact of specific macroinformation releases on the variances in time periods surrounding the information releases is analyzed. It is expected that, other things being equal, variances measured in sessions surrounding information releases will be larger than variances of similar sessions on other days with no major news releases. The increase in the magnitude of variances during sessions surrounding significant information releases should reflect traders' reaction to information arrival.

Information which affects trading of financial assets is generally produced continuously (French and Roll [54]). Such information includes public as well as private information. However, much information with impact on asset prices is not generated and disseminated continuously but is produced and released regularly at scheduled times. For the U.S. Treasury bond futures and Eurodollar futures contracts, such macroinformation series include: (1) monthly U.S. Merchandise Trade Balance figures, (2) weekly money supply figures, (3) monthly Industrial Production figures, and (4) monthly Consumer Price Index. In this study, the impacts of these macroinformation announcements on the patterns of variances for the U.S. Treasury bond futures and Eurodollar futures are examined (similar information announcements which are released in England and Japan are also used in tests to compare the relative impact of U.S. and overseas information). A list of selected studies which have considered the impacts of the four macroinformation series on the parameters of asset return distributions is presented in Table 5 (p. 64).

The four information series chosen have been shown to affect the distribution parameters of various assets. Castanias [22] reports that the average variance of the Standard and Poor Composite Index on days that Consumer Price Index (CPI) announcements as well as other federal statitics releases is significantly higer than the variance on the "non-event" days. Pearce and Roley [108] provide empirical evidence that stock prices respond negatively to unexpected inflation as measured by the CPI. The information regarding inflation rate conveyed by the CPI can cause investors to revise their assessment of future level of interest rates and money demand. To the extent that the prices of U.S. Treasury bond futures and Eurodollar futures are affected by investor's revisions of their expectations about future interest rates and demand for money, the price volatility of these futures contracts should increase in periods surrounding the announcements of the CPI. CPI is announced by the Bureau of Labor and Statistics on a monthly basis at 7.30 a.m. CST. Each announcement provides information about inflation during the preceding month.

TABLE 5

U.S. Macroeconomic Information Releases.

Type of information and time of release	Studies which have examined the impact of the information on parameters of asset return distributions
Consumer Price Index (7.30 a.m. CST; monthly)	Castanias [22], Pearce and Roley [108], Barnhart [7].
Money Supply (M1-3.10 p.m. CST; weekly)	Pearce and Roley [108], Cornell [32], Barnhart [7]
Industrial Production (8.30 a.m. CST; monthly)	Chen, Roll, Ross [23], Roley and Troll [113].
U.S. Merchandise Trade Balance (7.30 a.m. CST; monthly)	Deravi, Gregorowicz, and Hegji [37].

Notes:

1. Similar releases of macroinformation in the United Kingdom and Japan are not necessarily made at the same time of day as those of the U.S. releases.
2. U.K. releases are on a monthly basis.
3. Japanese releases are not made on a predetermined schedule. However, most releases take place once a month.

Information contained in the weekly money supply announcements by the Federal Reserve Bank is likely to affect the volatility of U.S. Treasury bond futures and Eurodollar futures contracts. Cornell [32] documents a significant positive correlation between announced money supply innovations and changes in yields on government securities of all maturities. Cornell argues that the weekly money supply announcements can have markedly destabilizing impact on long-run inflation expectations; thus also on the yields and prices of securities. Specifically, Cornell reports evidence of shifts in the entire term structure in response to unexpected change in money supply. Cornell suggests that the dramatic reaction of long-term yields to short-run money supply announcements is related to the money supply announcements being analyzed by market participants with the goal of determining whether another change in the Fed's rules is possible. The money supply announcements are usually made at 3.10 p.m. CST on Thursday afternoons.

The monthly announcements of the Industrial Production (IP) figures should also have impact on the variance patterns of the U.S. Treasury Bond futures and Eurodollar futures contracts. Monthly reports on real economic activity in the previous month that is contained in the IP announcements may cause investors to revise their portfolio compositions of equities, fixed income instruments, and derivative securities (Pearce and Roley [108], Barnhart [7]). Although the eventual impact of industrial output announcements on prices of various securities cannot be determined a priori, it is likely that the initial impact will be reflected in the short-run price movements of the two futures contracts in response to the announcements. Roley and Troll [113] examined the reactions of stock prices and interest rates, respectively, to industrial production announcements for the period from 1977-1984. Their results indicate an association between industrial production surprises and the value of stock prices and interest rates. The monthly industrial production figure for the preceding month is made on various days of the week on a monthly basis at 8.15 to 8.30 a.m. CST.

The monthly U.S. Merchandise Trade Balance announcements are likely to convey relevant information about the future level of interest rates as well as the strength of dollar. Investors' decisions to invest in U.S. government securities, e.g., the U.S. Treasury Bond cash and futures, should in part depend upon the outlook of the U.S. Economy that is reflected in the trade balance figures. Likewise, the demand for Eurodollar deposit can be affected by information about future value of dollar contained in the announcements of the trade balance statistics. The U.S. merchandise trade balance announcements are made on a monthly basis at 8.30 a.m. CST. Each trade balance report contains information about the trade statistics for the month before the preceding month while a Federal budget report provides the statistics on the government's budget for the preceding month.

Although not examined directly in this study, there are also other occasional economic events which are relevant to the trading of U.S. Treasury bond futures and Eurodollar futures. These include U.S. Treasury Bonds auctions, Treasury refundings, and other unique economic news (e.g., joint economic policy announcements by the U.S. and major allies on April 8, 1987, Japanese government announcing $ 43 billion fiscal stimulus package on June 1, 1987, testimonies of Federal Reserve Chairman regarding monetary targets and policies). The majority of information releases with significant impacts on the price movements of U.S. Treasury Bond futures and Eurodollar futures are likely to take place during U.S. business hours. This uneven clustering of information arrivals during the trading day can cause differential between variances measured over trading hours of the U.S. and foreign markets.

While dissemination of private information could also affect trading activity, it is likely that, the impact of public information will tend to dominate the impact of private information on the trading in Treasury securities. An explanation for this effect is that there should be relatively little private information available in the markets for Treasuries since the majority of relevant economic information for the Treasuries is produced and publicly released by government agencies (see also De Long, Shleifer, Summers, and Waldman [35] on behavior of investors in markets where little private information is available).

For the period from January, 1987 to November, 1988, release times and dates of the four economic news are obtained from the following sources: (1) the weekly International Economic Calendar available from S.G. Warburg Securities, (2) the Monthly Research Review published by Merril Lynch Capital Markets, (3) the annual chronology of economic events published in the Economic Perspectives of the Federal Reserve Bank of Chicago, and (4) the schedules of economic statistics releases published by the Office of Management and Budget (the data from U.K. and Japan covers the time periods from May, 1987 to November 1988 and September, 1987 to November 1988, respectively). It should also be noted that Japanese dates in most cases are expected dates of releases. In contrast to public macroinformation releases in the U.S. and U.K., similar information releases in Japan do not take place on a fixed and regular schedule. Japanese government agencies responsible for a particular release will; however, announce the date on which the information is expected to be released in a given month. While the release dates vary for a given type of information the expected and actual release dates of Japanese macroinformation mostly coincide. For all release dates, prices from periods preceding and immediately following the announcements are used to calculate the variances. These variance estimates are compared with the variances from the same periods on days without major news announcements.[33] The null hypothesis can be stated as follows:

$H6_0$: The average variances in sessions surrounding relevant information releases are similar to those in the same sessions on other days, ceteris paribus.

3.3.7 Effect of Information Days

To further assess the impacts of information releases on the patterns of variances, tests of trading/non-trading time variance differentials are performed with prices on the information days excluded. This will allow an examination of the patterns of variance after accounting for the information effect. If nonstationarity of variance is mainly due to uneven clustering of information in certain time periods, some reduction in variance differentials when the effect of information clustering is removed is expected. However, the magnitude of the reduction in variance differentials will depend upon the relative effects of information, transaction costs and liquidity in different markets. The null hypothesis can be stated as follows:

$H7_0$: Differences between variances measured in various trading and non-trading sessions do not decrease even when information date data is excluded from the analysis.

To compare the relative impact of information generated in U.S., U.K. and Japan, tests of trading and non-trading time variance differential are performed alternatively with only prices on information release days from each of the three countries. The results of these tests should indicate the relative importance of information released in different markets to investors who use the information to revise their beliefs. Since the principal markets for the U.S. Treasury bond futures and Eurodollar futures are located in the U.S.; it is expected that U.S.-generated information are most relevant to investors, and therefore, will have the greatest impact on the variance of the U.S. Treasury bond futures and Eurodollar futures.

It is anticipated that the relationship between trading/non-trading time and information effects will be reflected in relatively large magnitude of variances in periods surrounding information releases as the market adjusts to the impact of new information. The impact of information on trading and non-trading time variances will also be determined by the nature of the information released as well as the characteristics of relevant time periods. In addition, differentials in liquidity and transaction costs between markets can influence traders' response to information releases (see Grossman [64], Admati and Pfleiderer [2], Barclay et al. [6]). A summary of testable hypotheses is presented in Table 6 (p. 67).

TABLE 6

Summary of Testable Hypotheses.

Variance Estimates: Trading versus Non-trading Time

H_0: variance estimates are equal across trading and non-trading periods.

Hourly Variance Estimates: Calendar Time versus Transaction Time and Information Hypotheses

H_0: hourly variance estimates are equal across trading and non-trading periods (Strict Calendar time hypothesis).

Hourly Variance Estimates: Transaction Time versus Information Hypotheses

H_0: hourly variance estimates between trading periods are equal (Strict Transaction Time hypothesis).

Interday Pattern of Variance Estimates

H_0: variance estimates are equal across trading and non-trading periods on each day of the week.

Weekends and Holidays Impacts on Trading/Non-trading Time Variance Differential

H_0: Differential between trading and non-trading time variance estimates will not change when weekends and holidays are excluded from the analysis.

Information Release Effect

H_0: The average variance estimates from periods surrounding specific information releases will be similar to those from the same periods on non-information days.

Information Days Impact on Trading/Non-trading time Variance Differential

H_0: Differential between trading and non-trading time variance estimates will not decrease even when information day data is excluded from the analysis.

CHAPTER 4

EMPIRICAL RESULTS

In this chapter the empirical results are presented in the following order. First, the volatility of the U.S. Treasury bond futures and the Eurodollar futures is analyzed for trading and non-trading periods of the international markets for these contracts. Second, the impacts of weekends and holidays on trading/non-trading time return variance differential is examined. Lastly, the analysis of the effects of macroinformation releases on the patterns of variances for the two futures contracts are presented.

4.1 <u>Trading and Non-Trading Time Return Variances of the U.S. Treasury Bond Futures</u>

To examine the pattern of volatility for the U.S. Treasury bond futures, return variances of the futures contract are calculated for various trading and non-trading periods.[34] Two estimators of variances are used in the calculation: (1) the maximum likelihood estimator of the variance of the normal return distribution that is based on daily opening and closing prices, (2) the extreme-value estimator of variance (the Parkinson estimator) that is based on the daily high and low prices recorded for individual trading periods. Patterns of trading and non-trading time variances are analyzed for various subperiods from January 1986 to November 1988.

Due to the introduction of evening trading session on the CBOT for Monday to Thursday in April and for Sunday in September of 1987, the analysis of trading/non-trading time effect in the variance of the U.S. Treasury bond futures is performed separately for time period prior to the beginning of evening trading in April, 1987 and for time period from April to September, 1987 as well as time period following Semptember. In addition, to test for possible year and contract-month effects in the pattern of variances, the analysis is undertaken separately for each year and each contract month in the overall period from 1986 to 1988.

The results of the analysis for the period prior to the introduction of evening trading are presented in Table 7 (p. 70). During this time period, there are three trading sessions and one non-trading sessions for the U.S. Treasury bond futures. The maximum likelihood estimator of the variance for normal distribution (S^2) is calculated for trading sessions 1 (2.15 a.m. open LIFFE to 8 a.m. open CBOT), 2 (8 a.m. open CBOT to 10.10 a.m. close LIFFE), 3 (10.10 a.m. close LIFFE to 2 p.m. close CBOT), and non-trading session 4 (2 p.m. close CBOT to 2 .15 a.m. open LIFFE-next day). The Transaction or Trading time hypothesis would suggest that the variances would be similar for session 1, 2, and 3. The Calendar time hypothesis would predict that the magnitude of variances in various trading and non-trading sessions would be an increasing function of

TABLE 7

U.S. Treasury Bond Futures Return Variances: January 2, 1986 to April 29, 1987.

A. Return Variances of Trading and Non-Trading Sessions

Session:	(1)	(2)	(3)	(4)	Number of Days
Mon. to Fri.	.143	.180 (a)	.222 (a,b)	.125	269
Mon.	.087	.115	.184	.100	51
Tue.	.155	.104	.236	.128	58
Wed.	.163	.298	.210	.128	57
Thurs.	.117	.146	.130	.094	52
Fri.	.183	.202	.280	.179	51
Mon. to Thurs.	.135	.176 (a)	.208 (a,b)	.112	218
Return variances when holidays are included in the sample					
Mon. to Fri.	.148	.182	.223	.133	283

B. Hourly Return Variances of Trading and Non-Trading Sessions

Session:	(1)	(2)	(3)	(4)	Number of Days
Mon. to Fri.	.024 (a)	.083 (a,b,c)	.058 (a,b)	.010	269
Mon.	.015	.071	.048	.008	51
Tue.	.026	.048	.062	.001	58
Wed.	.027	.137	.055	.011	57
Thurs.	.020	.067	.034	.008	52
Fri.	.031	.093	.073	.015	51
Mon. to Thurs.	.023 (a)	.081 (a,b,c)	.054 (a,b)	.009	218

a: Using standard F-test, the variance of the session is significantly greater than the variance of session 4 at .01 level.
b: Using standard F-test, the variance of the session is significantly greater than the variance of sesssion 1 at .01 level.
c: Using standard F-test, the variance of the session is significantly greater than the variance of session 3 at .01 level.

the number of hours in each session. In contrast to the Transaction time and Calendar time hypothesis, the Information hypothesis would predict that the variances would be a function of information flow in individual sessions rather than a strict function of number of hours or classification of the sessions (i.e., trading or non-trading). The results in Table 7 indicate that the trading time variances of sessions 2 (.180) and 3 (.222) are significantly greater than the non-trading time variance of session 4 (.125). Moreover, the variances of session 2 is also significantly greater the variance of session 1 (.143). The differential between the variances estimated for trading session 1 and non-trading session 4, however, are not statistically significant. The observed differentials between variances are consistent with the prediction of the Information hypothesis which maintains that variances would vary with informational activity in individual time periods.

To provide an additional test the three hypotheses, the variances in part A of Table 7 are normalized by the number of hours in the corresponding sessions. The hourly variances of the U.S. Treasury bond futures for the period from January, 1986 to April, 1987 are presented in part B of Table 7. While the pattern of hourly variances is generally similar to the pattern of the overall variances, two differences between the results in parts A and B of Table 7 may be noted. First, on an hourly basis, the variance of session 1 (.024) is significantly greater than that of period 4 (.010). Second, the hourly variance of session 2 (.083) is now the greatest among all 4 sessions. Hourly variance results provides additional information regarding the three hypotheses examined in this analysis. The observed differences between the hourly variances between sessions 1, 2 and 3 as well as between sessions 1, 2, 3, and 4 are not consistent with the Calendar Time hypothesis which would predict that the hourly variances would be similar across trading and non-trading sessions. The normalized variance does not appear to be a strict function of hourly trading activity. Moreover, on both non-normalized and normalized basis, the differences between trading sessions 1,2, and 3 are not consistent with the strict interpretation of the Transaction time hypothesis which would suggest that the variances would be similar for trading sessions 1, 2, and 3.

The results in Table 7 are consistent with the Information hypothesis. According to the Information hypothesis, the return variances vary across time periods with the uneven flow of information. To the extent that relevant information for the U.S. Treasury bond futures trading tends to arrive in time periods surrounding or during the trading hours of the primary exchange and that the liquidity and transaction cost is highest (lowest) during these hours, greatest return variances will be expected during sessions 2 and 3. As reported in Table 7, the variances of sessions 2 and 3 which encompass the trading hours of the CBOT and LIFFE are indeed the greatest among the four time periods. The third greatest variance is observed in session 1 which covers the trading hours on LIFFE before the opening of the CBOT. While session 1 is a trading period, the smaller variance of this session most likely reflects the lower informatinal activity and lower liquidity in the U.K. market. The period with the lowest variance is period 4 which contains the time interval when both the futures and cash markets in the U.S. and U.K. are closed. In this period, other things equal, the volatility of the U.S. Treasury bond futures is expected to be relatively low due to reduced liquidity when major financial markets are closed.

The trading and non-trading time variances for the time period from May 6, 1987 to November 28, 1988 are presented in Table 8 (p. 74). During this period the U.S. Treasury bond futures contract trading is extended to the evening session on the CBOT (Monday to Thursday and Sunday). Thus, the trading sessions (1,3,4,5) and non-trading sessions (2,6) for this period of analysis are (1) 6 p.m. open CBOT-previous day to 9.30 p.m. close CBOT-previous day, (2) 9.30 p.m. close CBOT-previous day to 2.15 a.m. open LIFFE, (3) 2.15 a.m. open LIFFE to 8 a.m. open-CBOT, (4) 8 a.m. open CBOT to 10.10 a.m. close LIFFE, (5) 10.10 a.m. close LIFFE

TABLE 8

U.S. Treasury Bond Futures Return Variances:
May 6, 1987 to November 28, 1988.

A. Return Variances of Trading and Non-Trading Sessions
(excluding October 7 - 26, 1987)

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.	.049 (a)	.026	.110 (a,b)	.117 (a,b)	.162 (a,b)	.036	323
Mon.	.058	.029	.054	.085	.177	.011	52
Tue.	.065	.034	.088	.139	.168	.034	66
Wed.	.061	.027	.075	.132	.194	.022	72
Thurs.	.034	.018	.108	.076	.078	.034	70
Fri.	.027	.020	.217	.146	.192	.081	63
Mon.-Thurs	.054 (a)	.027	.084 (a)	.110 (a,b)	.152 (a,b)	.024	260
Return variances when holidays are included from the sample							
Mon. -Fri.	.054	.041	.119	.120	.168	.038	340

B. Hourly Return Variances of Trading and Non-Trading Sessions

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon-Fri.	.014	.006	.018 (a)	.054 (a,b)	.042 (a,b)	.009	323
Mon.	.017	.006	.009	.039	.046	.003	52
Tue.	.019	.008	.015	.064	.044	.009	66
Wed.	.017	.006	.013	.061	.051	.006	72
Thurs.	.010	.004	.018	.035	.020	.009	70
Fri.	.008	.004	.036	.068	.050	.020	63
Mon-Thurs.	.015	.006	.014 (a)	.051 (a,b)	.040 (a,b)	.006	260

a: Using standard F-test, the variance of the session is significantly greater than the variance of sessions 2 and 6 at .01 level.
b: Using standard F-test, the variance of the session is significantly greater than the variance of session 1 at .01 level.

to 2 p.m. close CBOT, and (6) 2 p.m. close CBOT to 6 p.m. open CBOT. The results in part A of Table 8 are also consistent with the Information hypothesis. Variances observed in sessions 5 (.162), 4 (.117), 3 (.110), and 1 (.049) are significantly greater than those observed in sessions 2 (.026) and 6 (.036). In addition, the variances in sessions 3, 4, and 5 are also significantly greater than that of session 1. Sessions 5 and 4 cover the trading hours on the CBOT and LIFFE while session 3 covers the morning and early afternoon trading on LIFFE and session 1 represents the evening trading on the CBOT. Although the futures markets in the U.S. and U.K. are closed during periods 2 and 6, the primary cash markets in the U.S. (e.g., the NYSE) are open during period 6. While it may be expected that, other things equal, the trading and informatinal activity during the hours of primary U.S. cash markets tends to increase the volatility of the U.S. Treasury bond futures, the variance of perid 6 is not different from that of period 2 during which the liquidity in the futures markets is the lowest and the liquidity in the cash markets is reduced.[35]

The variances presented in Table 8 are also normalized by the number of hours in individual time periods and are reported in part B of Table 8. The pattern of the hourly variances is similar to the pattern of variances reported in part A of Table 8. The distributions of trading and non-trading time variances in the two tables are consistent with the Information hypothesis with no evidence supporting the Calendar Time or Transaction Time hypotheses. Thus, results in Table 8 indicate that similar to the pattern of variances in the period prior to the introduction of the evening trading on the CBOT, the trading periods which encompass the hours of the CBOT and LIFFE exhibit the greatest return variances (5: 0.162 and 4: 0.117, respectively). The smallest variances are observed during the non-trading hours of the CBOT (.026) and LIFFE (.036). While the return variance of the evening trading on the CBOT is significantly greater than the variances of non-trading periods, its magnitude only ranges from one-third to one-half of those of the day time trading sessions. Since Sunday evening trading has been in effect only since September 17th, 1987, the trading/non-trading time analysis is performed separately for the time periods with and without Sunday evening trading to test for possible impact of Sunday trading on the pattern of U.S. Treasury bond futures variances. Results for the period from the introduction of the evening trading in April to the introduction of Sunday evening trading in September, and for the time period with Sunday trading are presented in Table 9 (p. 77). Prior to the period with Sunday trading, the return variances during the day time trading hours (3, 4, and 5) of the CBOT and LIFFE (.198, 0.138, and .128, respectively) remain the greatest while the variance during the non-trading session 2 (.024) is the lowest.

TABLE 9

U.S. Treasury Bond Futures Return Variances:
Pre and Post Sunday Evening Trading.

A. Pre Sunday Evening Trading
(May 1, 1987 to September 11, 1987)

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Tue.-Fri.	.078	.024	.128	.138	.198	.079	66
Mon.	np	np	np	np	np	np	np
Tue.	.092	.015	.044	.105	.276	.025	13
Wed.	.148	.019	.115	.164	.142	.030	18
Thurs.	.045	.024	.080	.062	.106	.049	17
Fri.	.040	.030	.265	.210	.256	.205	18
Tue.-Thurs	.094	.021	.089	.111	.163	.035	48

B. Post Sunday Evening Trading
(September 15, 1987 to November 28, 1988)

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.	.043 (a)	.026	.108 (a,b)	.112 (a,b)	.153 (a,b)	.026	261
Mon.	.057	.029	.054	.085	.177	.011	52
Tue.	.060	.040	.099	.148	.141	.025	53
Wed.	.038	.029	.061	.119	.211	.020	55
Thurs.	.031	.018	.116	.074	.068	.030	54
Fri.	.026	.017	.214	.139	.165	.047	47
Mon-Thurs.	.047 (a)	.029	.085 (a,b)	.107 (a,b)	.150 (a,b)	.021	214

a: Using standard F-test, the variance of the session is greater than the variances of sessions 2 and 6 at .01 level.
b: Using standard F-test, the variance of the session is greater than the variance of session 1 at .01 level.

Notes:

1. Since there is no Sunday trading for part A, Monday prices are not included in the analysis.
2. For part B, the variance of session 1 on Monday is that of Sunday evening trading session.

The variance of the afternoon non-trading session 6 (.079) seems high relatively to the overnight non-trading session 2; however, as the discussion on the impact of weekends (section 4.1.3) will indicate, the return variance in session 6 is substantially reduced when the results are adjusted for the impact of weekend (.035).

The results of the analysis for the time period during which Sunday evening trading takes place are presented in Part B of Table 9. Similar to the pattern of variances during the period with evening trading only on Monday to Thursday, the greatest variances are reported for the day time trading sessions 5 (.153), 4 (.112), and 3 (.108) and the lowest variances for the non-trading sessions 2 (.026) and 6 (.026). Comparing the variances of the evening trading sessions, Sunday trading does not appear to add to the volatility of the returns on the U.S. Treasury bond futures. In fact, for the periods analyzed, the return variance of the evening trading session without Sunday is greater than that of similar session with Sunday. The differential, however, appear to be largely due to high return variance of the evening trading on Wednesday during the time period without Sunday trading. When Wednesdays are excluded from the analysis, the variances of the evening trading sessions become more similar (result available from the author).

4.1.1 U.S. Treasury Bond Futures: Interday Pattern of Variance

Results from Tables 7 to 9 show that the pattern of trading/non-trading time variances reported on the overall basis (i.e., results for Mon-Fri.) generally exists on each day of week. On individual weekdays, the variances are greatest during the daytime trading sessions which encompass the trading hours of the CBOT and LIFFE. In contrast, the lowest variances are reported during the non-trading hours of the futures markets. The evening trading on Monday to Thursday and on Sunday generally exhibits lower volatility than the daytime trading sessions. It is important to note; however, that minor variations from the overall variance patterns exist in the variance pattern on some weekdays. Due to the inclusion of the weekend returns in the non-trading period that begins on Friday afternoon, the return variance of that period tends to be greater than the variance of similar period on Monday to Thursday (the impact of weekend returns will be discussed in the next section). While the variances of the daytime trading sessions are greater than other sessions on all weekdays, the order of the magnitude of these variances can vary from day to day. Although not always statistically significant, the variances of the trading sessions on Fridays tend to be greater than those of similar sessions on other weekdays. In contrast, the lowest trading time variances tend to be observed on

Thursday. If the liquidity and trading costs in various intraday time intervals are similar across weekdays, the variations in the order of the variances of daytime sessions are likely to be due to unique information flow and perhaps, the patterns of trading activity associated with individual weekdays.

4.1.2 U.S. Treasury Bond Futures: Impact of Weekends and Holidays

The impact of holidays in the analysis is reflected in the greater magnitude of variances relative to the variances calculated from the sample with holidays excluded.[36] However, as shown in part A of Tables 7 and 8, with the exception of non-trading sessions 4 (2 p.m. to 2.15 a.m. in Table 7) and 2 (9.30 p.m. to 2.15 a.m. in Table 8), the differences between variances due to the inclusion of holidays are not significant. The relatively large return variance of session 4 when holidays are included in the sample is expected since on trading days preceding holidays the returns of the session are in fact multi-days returns. Likewise, the returns measured for the non-trading session 2 (Table 8) on days following holidays are also multi-days returns. As shown in Table 7, the inclusion of holidays does not affect the pattern of trading and non-trading time variances. While the inclusion of holidays in Table 8 results in the variances of the two non-trading sessions (2 and 6) becoming more similar, the overall relationship between trading and non-trading time variances remains identical to that observed when holidays are excluded. Thus, while holidays can affect the magnitude of the U.S. Treasury bond futures return variances, they do not significantly alter the overall pattern of trading and non-trading time variances.

The impact of weekends on the estimation of return variances for the U.S. Treasury bond futures is evident in the results presented in Tables 7 to 9. Specifically, the impact of weekends is reflected in the relatively large magnitude of the return variance of the non-trading session 4 in parts A (.125) and B (.010) of Table 7, and non-trading session 6 in Tables 8 and 9 reported for Friday (.081, .205, .047, respectively). During the pre-evening trade time period, the non-trading session 4 on Fridays covers the weekend interval from the closing on the CBOT at 2 p.m. to the opening on the LIFFE on Monday at 2.15 a.m. After the introduction of evening trading on Monday to Thursday, the afternoon non-trading session on Fridays represents the weekend interval from 2 p.m. to the opening of LIFFE at 2.15 a.m. on Sunday while with the addition of the trading on Sunday, the afternoon non-trading session on Fridays runs from 2 p.m. to 6 p.m. on Sunday. Past studies (e.g., Phillips-Patrick and Schneeweis [109] and French [52]) have examined the impact of weekends on the distributional parameters of the return distribution. In general, these studies have reported that the return variance for the weekends is greater than that of the overnignt period during weekdays; however, not by the magnitude predicted by the Calendar Time hypothesis. As shown in Tables 7 to 9, the return variances of session 4 in part A (.125) and B (.010) of Table 7, session 6 in part A (.036) of Table 8, and part B (.079) of Table 9 generally decrease when Fridays are excluded from the anlysis (.112, .009, .024, .035, respectively). While the decrease in variance is not always significant, the most drastic reduction in return variance due to the exclusion of the weekends is reported for the period of analysis when evening trading is limited to Monday to Thursday (Table 9, part A). With weekends included in the analysis (Monday to Friday), the variance of session 6 (.079) is approximately the same as that of the evening trading session 1 (.078). However, with Fridays excluded the variance of period 6 decreases by 50 percent, resulting in a higher degree of similarity among the patterns of variances reported for time periods after the introduction of the evening trading in April of 1987 (Tables 8 and 9). Overall, relative to other days of the week, the presence of weekends is manifest in the relatively large return variance for the non-trading period which begins at 2 p.m. on Fridays. When the impact of weekends is removed from the analysis (Monday to Thursday), the observed trading and non-trading time variances constitutes a pattern which conform even more closely to the variance pattern that would be expected under the Information hypothesis.

4.2 Trading and Non-Trading Time Return Variances of the Eurodollar Futures

The period of analysis for the Eurodollar futures is from January, 1987 to November, 1988. Unlike the U.S. Treasury bond futures, the number of trading and non-trading sessions for the Eurodollar futures remain the same for the entire period of analysis. The trading and non-trading sessions for the Eurodollar include: (1) 6.30 p.m. open SIMEX to 2.30 a.m. open LIFFE, (2) 2.30 a.m. open LIFFE to 7.20 a.m. open CME, (3) 7.20 a.m. open CME to 10 a.m. close LIFFE, (4) 10 a.m. close LIFFE to 2 p.m. close CME, and (5) 2 p.m. close CME to 6 p.m. open SIMEX-next day. The trading and non-trading time return variances for the Eurodollar futures are presented in Table 10 (p.84).

Relative to the U.S. Treasury bond futures, variances of the return on the Eurodollar futures contract are of smaller magnitude. Similar to the pattern of U.S. Treasury bond futures trading and non-trading time variances, the observed pattern of return variances for the Eurodollar futures conform to the pattern of variances expected to exist under the Information hypothesis. The greatest variances are reported for the trading sessions 3 (.0026) and 4 (.0025) when both the CME and LIFFE are open for trading. The next greatest variance are reported for the trading sessions on

TABLE 10

Eurodollar Futures Return Variances:
January 5, 1987 to November 29, 1988.

Session:	(1)	(2)	(3)	(4)	(5)	Number of days
Mon.-Fri.	.0011	.0008	.0026 (a,b)	.0025 (a,b)	.0010	376
Mon.	.0010	.0006	.0009	.0023	.0007	67
Tue.	.0011	.0009	.0025	.0030	.0008	79
Wed.	.0009	.0009	.0025	.0021	.0009	84
Thurs.	.0010	.0007	.0012	.0017	.0008	78
Fri.	.0008	.0012	.0062	.0037	.0013	68
Mon-Thurs.	.0010	.0008	.0018 (a,b)	.0022 (a,b)	.0008	308
Return variances when holidays are included from the sample,						
Mon-Fri.	.0013	.0010	.0029	.0026	.0025	404

a: Using standard F-test, the variance of the session is significantly greater than the variance of session 5 at .01 level.

b: Using standard F-test, the variance of the session is significantly greater than the variance of session 1 at .01 level.

SIMEX 1 (.0011). The lowest variance; however, is observed for the trading session 2 (.0008) when the LIFFE is open for trading. Although not statistically significant, the return variance estimated for the non-trading session 5 (.0010) is slightly greater than that of session 2. The differential between the volatility estimates for these two sessions may be due to the information-induced price movements related to trading activity during the afternoon hours of the U.S. cash and foreign exchange markets that are included in session 5. In contrast, although foreign exchange trading also takes place during the hours of the LIFFE (session 2), liquidity and trading in the U.S. cash intruments is much reduced during these hours. Lastly, while it is not surprising that the volatility of the Eurodollar futures is greatest during the hours that both the primary exchange CME and the European exchange LIFFE are open, it is interesting to note that the volatility of the Eurodollar futures returns appears to be greater during the hours of the Far East exchange SIMEX than during those of the LIFFE.

4.2.1 Eurodollar Futures: Interday Pattern of Variance

Results in Table 10 shows that a trading and non-trading time variance pattern similar to the overall pattern exists on all days of the week. However, the magnitude of the estimated return variances for individual sessions can vary from day to day. For instance, the return variance of session 3 (open CME to close LIFFE) ranges from .0009 on

Monday to .0062 on Friday. Except for session 1 which represents the trading hours on the SIMEX, return variances on Friday are greater than those in corresponding sessions on other days of the week. As with interday variance patterns of the U.S. Treasury bond futures, for the Eurodollar futures the session with the greatest variance (session 3 or 4) vary across weekdays. Session 2 which covers the morning trading on LIFFE exhibits the lowest volatility on all days of the week. Moreover, the trading time variances of the Eurodollar futures also tend to be greatest on Friday and lowest on Thursday; perhaps reflecting the pattern of information processing across weekdays in the markets.

4.2.2 Eurodollar Futures: Impact of Weekends and Holidays

The impacts of weekends and holidays can be seen by comparing the overall variance patterns (Monday to Friday) of the Eurodollar futures reported in Table 10. In contrast to the variance pattern shown in Table 10 that is obtained with holidays excluded from the analysis, when holidays are included in the analysis the return variances are greatest for trading sessions 3, 4 and non-trading session 5, respectively. As expected, the impact of holidays inclusion is most pronounced on the magnitude of the variance of non-trading session 5. The relatively large variance of session 5 when holidays are included in the sample is due to the fact that on trading days preceding the holidays, the returns over session 5 are actually multi-day returns.[37] Unlike the variances of sessions 1 and 5, the variances of sessions 2, 3, and 4 remain largely unchanged when holidays are excluded from the analysis. For the period of analysis, the impact of weekends on the variance pattern of the Eurodollar Futures is minimal. Regardless of whether holidays are included in the analysis, return variances, especially that of session 5 (from Friday closing on the CME at 2 p.m. to opening on SIMEX at 6.30 p.m. on Sunday, Chicago time) do not change significantly when Fridays are excluded from the estimation of return variances.

4.3 Return Variances: Year and Contract Month Effects

In this section, the analysis of trading/non-trading time variance differential is extended to time periods including individual years as well as individual intervals associated with each of the four contract months for the U.S. Treasury bond futures and Eurodollar futures. The analysis based on the partitions of the overall sample by year and contract months tests for any seasonality that may exist in the patterns of returns variances of the futures contracts expiring in each year as well as at different times of the year chosen in this study.[38] The variance patterns of the U.S. Treasury bond futures and Eurodollar futures associated with each contract months during the period of analysis are reported for Monday to Friday subsample and Monday to Thursday subsample. While not numerically presented in this study, similar results for individual weekdays are available from the author.

4.3.1 U.S. Treasury Bond Futures

The return variances of the U.S. Treasury bond futures for the periods from January to December, 1986; April to December, 1987; January to November, 1988 are reported in Tables 11 and 12 (p. 89 and 90, respectively). The observed pattern of variances estimated from daily prices in 1986 is similar to the pattern of variances reported for the period from January, 1986 to the beginning of evening trading in April 1987 (Table 7). The greatest variances are reported for trading sessions 2 (.193) and 3 (.242) which cover the trading hours on the CBOT and LIFFE. The lowest variance is reported for the non-trading session 4 (.138) when the futures markets are closed. In addition, return variances of sessions 2 and 3 are significantly greater than that of session 1 (.170) which represents the first half of daytime trading on the LIFFE. Since return variances of the U.S. Treasury bond futures in 1987 (Table 12, part A) are based on the time period which includes evening trading, they are not strictly comparable to those estimated in 1986. Notwithstanding the addition of evening trading session in 1987, the return variances of successive trading sessions which cover the time interval from the opening on the LIFFE (2.15 a.m.) to the closing on the CBOT (2 p.m) in 1986 (sessions 1, 2, and 3) are greater than those of similar

TABLE 11

U.S. Treasury Bond Futures Return Variances: 1986.

Time period: January 2, 1986 to December 31, 1986

Session:	(1)	(2)	(3)	(4)	Number of days
Mon.-Fri.	.170	.193	.242	.138	200
	(aa)	(a,bb)	(a,b)		
Mon.	.096	.138	.207	.114	39
Tue.	.212	.101	.274	.147	45
Wed.	.200	.375	.225	.137	41
Thurs.	.130	.163	.119	.105	39
Fri.	.208	.191	.283	.184	36
Mon.-Thurs.	.162	.195	.231	.126	164
	(aa)	(a,bb)	(a,b)		

a: Using standard F-test, the variance of the session is significantly greater than the variance of session 4 at .01 level.
aa: Using standard F-test, the variance of the session is significantly greater than the variance of session 4 at .05 level.
b: Using standard F-test, the variance of the session is significantly greater than the variance of session 1 at .01 level.
bb: Using standard F-test, the variance of the session is significantly greater than the variance of session 1 at .05 level.

TABLE 12

U.S. Treasury Bond Futures Return Variances: 1987 and 1988.

A. May 1, 1987 to December 30, 1987

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon-Fri.	.088 (c)	.034	.124 (a,b)	.164 (a,b)	.205 (a,b)	.069	115
Mon.	.142	.031	.030	.123	.386	.013	11
Tue.	.115	.050	.083	.190	.258	.034	26
Wed.	.102	.024	.102	.227	.156	.027	28
Thurs.	.058	.033	.138	.062	.110	.070	26
Fri.	.042	.029	.232	.191	.227	.185	24
Mon.-Thurs	.100	.036	.098 (c)	.159 (a,b)	.192 (a,b)	.039	91

B. January 4, 1988 to November 28, 1988

Sessions:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.	.028	.021	.102 (a,b)	.089 (a,b)	.137 (a,b)	.018	208
Mon.	.039	.027	.061	.077	.129	.010	41
Tue.	.030	.024	.091	.110	.114	.019	40
Wed.	.035	.029	.059	.075	.214	.018	44
Thurs.	.019	.010	.082	.072	.060	.013	44
Fri.	.018	.015	.210	.116	.161	.028	39
Mon.-Thurs.	.030	.022	.077 (a,b)	.083 (a,b)	.131 (a,b)	.015	169

a,b: Using standard F-test, the variance of the session is significantly greater than the variances of sessions 2 and 3, respectively at .01 level.
c: Using standard F-test, the variance of the session is significantly greater than the variance of session 2 at .01 level.

sessions in 1987 (sessions 3, 4, and 5). Differences in the magnitude of these variances can be related to a number of factors including the redistribution of the 24-hour return variance due to the addition of evening trading (shortening of non-trading time) as well as fundamental changes in the structure of interest rates affecting the prices of the U.S. Treasury bond futures during 1986 and 1987. Lastly, it should be noted that in contrast to the results reported for the period from the introduction of evening trading to November, 1988 (Table 8, part A); with Fridays excluded from the analysis for 1987, the variances of trading session 3 (open CBOT to close LIFFE) become similar in magnitude to that of the evening trading session on the CBOT (.098 and .100).

The trading and non-trading time variances of the U.S. Treasury bond futures estimated from prices recorded in 1988 exhibit a pattern similar to those reported for time periods after the introduction of evening trading (Table 9). The pattern observed in 1988 is also the same as that in 1987. In terms of their magnitude, return variances of all sessions estimated for 1988 are much lower than those of similar sessions estimated for 1987 and 1986. The decrease in estimated return variances may be due a number of factors including a general decline of the volatility in the interest rate or a change in information environment.

The trading and non-trading time variances of the U.S. Treasury bond futures estimated from prices of each nearby contract in 1986, 1987, and 1988 are presented in Table 13 (p. 93). The variances in the trading and non-trading sessions for the March 1986 and March 1987 contracts are similar in magnitude. In addition, the variances of the returns for the two contracts exhibit the same general pattern with the greatest variances observed during the trading sessions of the CBOT and LIFFE and the lowest variance during the non-trading session (2 p.m. to 2.15 a.m. the next day). The variances of the March 1988 contract exhibit a pattern similar to the overall pattern of variances observed for time periods after the introduction of the evening trading. The magnitude of the variances of the trading sessions which encompass the hours of the CBOT and LIFFE are also comparable to those of similar hours in 1987 and 1986.

On an overall basis, the variances of the U.S. Treasury bond futures for the June 1986, 1987, and 1988 contracts constitute patterns that are consistent with the trading/non-trading time and information effects discussed earlier. It should be noted; however, that except for trading session 3 (close on LIFFE to close on CBOT) the return variances of the U.S. Treasury bond futures for the June 1986 contract are greater than those for the March 1986 contract. Likewise, the return variances of the trading and

TABLE 13

U.S. Treasury Bond Futures Return Variances:
March, June, September, December Contracts.

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
March contracts							
1986							
Mon.-Fri.	.136	.157	.214	.063			34
Mon.-Thurs	.129	.146	.224	.046			29
1987							
Mon.-Fri.	.073	.118	.174	.052			56
Mon.-Thurs	.059	.088	.121	.042			45
1988							
Mon.-Fri.	.088	.044	.132	.140	.195	.019	49
Mon.-Thurs	.095	.047	.105	.120	.205	.020	44
June contracts							
1986							
Mon.-Fri.	.203	.185	.250	.206			42
Mon.-Thurs	.198	.202	.208	.234			33
1987							
Mon.-Fri.	.064	.129	.144	.070			33
	(.084)	(.021)	(.216)	(.046)	(.297)	(.097)	12
Mon.-Thurs	.040	.126	.148	.061			26
	(.128)	(.029)	(.129)	(.025)	(.194)	(.065)	8
1988							
Mon.-Fri.	.014	.020	.070	.081	.113	.011	56
Mon.-Thurs	.015	.023	.047	.066	.110	.013	47

Continued, next page

Table 13 (continued)

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of Days
<u>September contracts</u>							
1986							
Mon.-Fri.	.190	.142	.268	.111			49
Mon.-Thurs	.166	.133	.279	.090			39
1987							
Mon.-Fri.	.068	.017	.098	.128	.188	.069	48
Mon.-Thurs	.080	.012	.073	.106	.170	.029	36
1988							
Mon.-Fri.	.035	.005	.122	.084	.157	.022	61
Mon.-Thurs	.039	.005	.113	.093	.157	.017	48
<u>December contracts</u>							
1986							
Mon.-Fri.	.141	.145	.196	.197			52
Mon.-Thurs	.140	.134	.210	.097			43
1987							
Mon.-Fri.	.094	.045	.147	.229	.206	.069	41
Mon.-Thurs	.100	.049	.130	.230	.211	.053	33
1988							
Mon-Fri.	.013	.027	.082	.072	.113	.020	56
Mon-Thurs	.012	.027	.048	.061	.090	.013	44

Notes:

1. For all contracts in 1986, March and the first half of June contract (before the introduction of evening trading in April) in 1987, sessions 1 to 4 are as defined in Table 7. For all contracts from June 1987 (after the introduction of evening trading) to December 1988, sessions 1 to 6 are as defined in Table 8.
2. The numbers in parentheses are variances of the June 1987 contract after the introduction of evening trading on the CBOT.

non-trading sessions for the June 1987 contract exceed those of similar sessions for the March 1986 contract. However, the increase in variances of the June contract relative to the March contract does not continue in 1988. In contrast, the variances of the June 1988 contract are lower than those of similar sessions of the March 1988 contract.

The variances associated with the the September contract of the U.S. Treasury bond futures in 1986, 1987, 1988 exhibit a pattern that is expected under the Information hypothesis. Moreover, the results in Table 13 indicate that the expected differential between trading and non-trading time variances are highly pronounced and statistically significant for the September contract in all three years. In terms of magnitude, the return variances decrease slightly from the June contract to September contract in 1986 while the variances increase slightly from June contract to September contract in 1987 and 1988.

Similar to the patterns of variances associated with the other three contract months, the variances of the U.S. Treasury bond futures for the December contract in all three years form patterns that are consistent with the existence of trading/non-trading time and information effects. In 1986 the variances of the September and December contracts are similar in magnitude while in 1987 the variances of the December contract are generally greater than those of the September contract. The changes in the magnitude of the return variances of various sessions are less uniform for the September and December contracts in 1988. Increases as well as decreases in variances of different sessions are observed when the two contracts are compared.

Results in Tables 11 to 13 suggest that for the period chosen in this study, no seasonality associated with the year and contract month effects in the distribution of trading and non-trading return variances of the U.S. Treasury bond futures can be identified clearly. However, an observation regarding the degree to which the variance patterns of various time periods examined (i.e., yearly and quarterly subperiods) conform to the expectation based on the Information hypothesis should be noted. Of all time periods examined, the variances associated with the September contract in all three years form patterns that most clearly exhibit the trading/non-trading time and information effects in the distribution of U.S. Treasury bond futures variances. The sessions with the greatest variances are those during which the primary exchange CBOT and the U.K. exchange LIFFE are open. The lowest variance is observed for the only non-trading session 4 of the September 1986 contract and for non-trading session 2 of the September 1987 and 1988 contracts, which represents the time period during which all futures markets are closed and the informational and trading activity in the cash markets is much reduced. Equally important, the differentials between the trading and non-trading sessions of the subperiod associated with the Semptember contract in all three years are the most pronounced among all time periods examined.

4.3.2 Eurodollar Futures

The trading and non-trading time variances of the Eurodollar futures for 1987 and 1988 and for individual contract months are presented in Table 14 (p. 98) and Table 15 (p. 99), respectively. The pattern of return variances observed in each of two years is similar to the overall pattern of the Eurodollar futures variances reported earlier. The greatest return variances are reported for trading sessions 3 and 4 which encompass the trading on the CME and LIFFE. The lowest variance is reported for either trading session 2 (LIFFE) or the non-trading session 5 when the futures markets are closed and the U.S. cash markets are open. While the return variances for all sessions appear to decrease slightly from 1987 to 1988, the differentials between variances remain similar for the two years. Overall, no significant differences between the patterns of Eurodollar futures variances are detected for 1987 and 1988.

The return variances of Eurodollar futures for the four contract months in 1987 and 1988 are presented in Table 15. The variance patterns of the March 1987 and 1988 contracts are similar to the overall variance pattern for the Eurodollar futures. The return variances of all sessions are greater for the March 1988 contract. However, the

TABLE 14

Eurodollar Futures Return Variances:
1987 and 1988.

Session:	(1)	(2)	(3)	(4)	(5)	Number of days
A. January 5 to December 31, 1987						
Mon.-Fri.	.0011	.0012	.0026	.0032	.0010	195
Mon.	.0012	.0005	.0012	.0030	.0010	36
Tue.	.0015	.0013	.0028	.0045	.0013	42
Wed.	.0011	.0014	.0027	.0024	.0010	36
Thurs	.0010	.0007	.0009	.0022	.0006	38
Fri.	.0009	.0017	.0056	.0048	.0013	33
Mon.-Thurs	.0013	.0010	.0019	.0030	.0010	162
B. January 4 to November 29, 1988						
Mon.-Fri.	.0007	.0005	.0026	.0017	.0007	182
Mon.	.0007	.0007	.0006	.0016	.0003	31
Tue.	.0006	.0004	.0021	.0014	.0002	37
Wed.	.0006	.0003	.0022	.0018	.0005	38
Thurs.	.0009	.0006	.0014	.0011	.0010	41
Fri.	.0007	.0007	.0071	.0028	.0012	35
Mon.-Thurs	.0007	.0005	.0017	.0014	.0005	147

TABLE 15

Eurodollar Futures Return Variances:
March, June, September, December Contracts.

Session:	(1)	(2)	(3)	(4)	(5)	Number of days
March contracts						
1987						
Mon.-Fri.	.0006	.0004	.0012	.0010	.0003	36
Mon.-Thurs	.0007	.0004	.0008	.0010	.0004	27
1988						
Mon.-Fri.	.0013	.0008	.0032	.0040	.0011	49
Mon.-Thurs	.0014	.0008	.0020	.0042	.0004	41
June contracts						
1987						
Mon.-Fri.	.0010	.0012	.0019	.0036	.0012	51
Mon.-Thurs	.0011	.0007	.0013	.0040	.0012	42
1988						
Mon.-Fri.	.0006	.0004	.0022	.0012	.0009	56
Mon.-Thurs	.0006	.0004	.0014	.0009	.0010	45
September contracts						
1987						
Mon.-Fri.	.0010	.0008	.0025	.0019	.0008	55
Mon.-Thurs	.0010	.0009	.0018	.0018	.0008	46
1988						
Mon.-Fri.	.0005	.0004	.0023	.0018	.0003	56
Mon.-Thurs	.0004	.0004	.0014	.0014	.0003	46
December contracts						
1987						
Mon.-Fri.	.0031	.0020	.0040	.0050	.0010	43
Mon-Thurs	.0034	.0021	.0040	.0034	.0008	35
1988						
Mon.-Fri.	.0007	.0007	.0028	.0014	.0003	34
Mon.-Thurs	.0005	.0005	.0018	.0010	.0002	27

differentials between variances do not differ significantly between the March 1987 and March 1988 contracts. The pattern of variances for the Eurodollar futures June 1987 contract differs slightly from other patterns of Eurodollar futures variances examined. In contrast to earlier results, the magnitude of return variance of the non-trading session 5 (closing on the CME at 2 a.m. to opening on the SIMEX at 6 p.m. Chicago time) for the June 1987 contract is greater than those of trading sessions 1 (opening on SIMEX to opening on LIFFE) and 3 (opening on CBOT to closing on LIFFE). With the exception of session 5 variance, the magnitude of the remaining variances are as expected given the trading/non-trading time effect observed in time periods analyzed earlier. For the June 1988 contract no return variance of unusual magnitude is observed. The variances of the June 1988 contract are lower than those of the March 1988 contract, especially the variance of session 5 (.0042 in 1987 versus .0009 in 1988).

The patterns of trading and non-trading time variances of the Eurodollar futures for the September contract in 1987 and 1988 are similar to the other patterns observed earlier (with the exception of the June 1987 contract). It should be noted; however, that the lowest variance is reported for the non-trading session 5 in both years. There are no significant changes in the magnitude of the return variances between the June and September contracts in 1987 and 1988 except for the decrease in the variance of the non-trading session 5 that is due to the unusually high variance of that session for the June 1987 contract. For 1987 and 1988 the variances of the Eurodollar December contract are generally similar to those of the September contract. The greatest variances are reported for the hours during which both the CME and LIFFE are open for trading. The lowest variance is observed in the non-trading session 5 of the December contract in both years. However, for the December 1987 contract the return variance of session 2 which represents the morning and early afternoon trading hours on the LIFFE is high relative to the variance of the same session reported for other Eurodollar futures contracts.

Results in Tables 14 and 15 suggest that no year or contract month effects exist in the distribution of the Eurodollar futures trading and non-trading time return variances for time period chosen in this study. In sum, the patterns of return variances observed for the overall 1987-1988 time period as well as for individual years and contract months are generally consistent with the view that the trading/non-trading time variance effect is related to information arrival process.

4.4 An Extreme Value-Based Estimator of Variance

In this section, the Parkinson estimator of variance (P^2) that is based on the daily high and low prices is used to compare the volatility between trading sessions for the

U.S. Treasury bond futures and Eurodollar futures contracts. To the extent that trading/non-trading time and information effects exist in the distribution of the variances of the two futures contracts, the high-low P^2 estimator should attain the greatest value during the hours that the primary exchanges (i.e., the CBOT and the CME) are open for trading. Lower P^2 valued are expected for the trading sessions of non-U.S. exchanges (i.e., the LIFFE and the SIMEX).

4.4.1 U.S. Treasury Bond Futures: Trading Time High-Low Variance Estimator

The high-low variances (P^2) for the U.S. Treasury bond futures trading sessions on the LIFFE and CBOT for time periods prior to and after the introduction of the evening trading are presented in Table 16 (p. 103). As expected, the results in Table 16 show that for the period from January 1986 through April 1987, the high-low variance is greater during the trading hours on the CBOT (8 a.m. to 2 p.m.) than during those on the LIFFE (2.15 a.m. to 10.10 a.m.). Similar pattern of high-low variances exist on all days of the week. While no weekend effect similar to that discussed in earlier analysis in which both trading and non-trading sessions are considered is expected, the high-low variances are greatest on Friday (daily results available from the author). It is important to note that similar to the S^2 estimator, the high-low variances can be affected by the hours during which the trading on the LIFFE and CBOT

TABLE 16

U.S. Treasury Bond Futures:
High-Low Variances of Trading Sessions.

Session:	$CBOT_{eve.}$	LIFFE	$CBOT_{day.}$	Number of days
January 2, 1986 to April 29, 1987 (pre evening trading)				
Mon.-Fri.		.271	.399	266
Mon.-Thurs.		.242	.378	215
May 5, 1987 to November 28, 1988 (post evening trading)				
Mon.-Fri.	.040	.223	.249	324
Mon.-Thurs.	.043	.185	.229	259
May 5, 1987 to September 11, 1987 (pre Sunday evening)				
Mon.-Fri.	.064	.283	.337	65
Mon.-Thurs.	.075	.190	.317	48
September 15, 1987 to November 28, 1988 (post Sunday evening)				
Mon.-Fri.	.034	.208	.226	259
Mon.-Thurs.	.036	.184	.209	211
January 2, 1986 to December 31, 1986				
Mon.-Fri.		.312	.445	197
Mon.-Thurs.		.278	.424	161
May 5, 1987 to December 30, 1987				
Mon.-Fri.	.061	.276	.340	114
Mon.-Thurs.	.067	.203	.317	89
January 4, 1988 to November 28, 1988				
Mon.-Fri.	.029	.194	.198	210
Mon.-Thurs.	.030	.176	.198	170

Notes:

1. The hours of $CBOT_{eve.}$ are 6 p.m. to 9.30 p.m.
2. The hours of LIFFE are 2.15 a.m. to 10.10 p.m.
3. The hours of $CBOT_{day.}$ are 8 a.m. to 2 p.m.

overlaps (8 a.m. to 10.10 a.m.). In Table 16 the high-low variances for the evening and morning trading sessions on the CBOT as well as the trading session on the LIFFE are also reported for the time period from April, 1987 through November, 1988. The high-low variance of the U.S. Treasury bond futures is greatest during the morning trading hours on the CBOT (8 a.m. to 2 p.m.) and lowest during the evening trading hours on the CBOT (6 p.m. to 9.30 p.m.). Both the high-low variances during the trading sessions on the CBOT and LIFFE are significantly greater than that of the CBOT evening trading (.249, .223, and .040, respectively). While this pattern of high-low variances is present on all weekdays, the high-low variances tend to be greatest on Friday (results available from the author).

The time period after the introduction of the evening trading on the CBOT is further divided into the periods prior to and after the extension of evening trading to Sunday in September, 1987. The results for the high-low trading time variances for these two periods are presented in Table 16. The patterns of variances shown in Table 16 indicate that the greatest variance is observed for the CBOT morning trading and the lowest variance is reported for the CBOT evening trading. Consistent with earlier results for the S^2 variance estimator, on an overall basis, the high-low variances of the U.S. Treasury bond futures during the time period with evening trading are greater during the subperiod prior to the introduction of Sunday evening trading. In addition, the high-low variances on Friday are the greatest among all weekdays.

The high-low trading time variances of the U.S. Treasury bond futures for 1986, 1987, and 1988 are also reported in Table 16. A pattern of high-low variances similar to those reported above is present in all years. As is the case with the interyear pattern of the S^2 variances, for the trading sessions on the CBOT and LIFFE the high-low trading time variances appear to be greatest in 1986 and lowest in 1988. The largest decreases in these variances occur from 1987 to 1988 when the magnitude of the variances decline by 40% to 50% for the CBOT morning and evening trading sessions, respectively.

While the numerical results are not presented in this study, the analysis of contract month subsamples shows no unusual pattern of high-low variances the U.S. Treasury bond futures associated with individual contract months (results available from the author). For the CBOT and LIFFE trading hours, the high-low variances are greatest for the March 1988 contract. For the June contract, the high-low tradinn time variances for the CBOT and LIFFE are greatest in 1986 and lowest in 1988. It should be noted; however, that for the variances for the June 1987 contract are based on prices from March and April, 1987 only (i.e., before the beginning of evening trading on the CBOT). Of interest is the pattern of high-low variances of the U.S. Treasury bond futures for the June 1988 contract. Results show that based on the high-low variance estimator, the differential between the high-low variance of the CBOT morning trading and the LIFEE trading (.020 differential) is approximately one-third that of the March 1988 contract (.062 differential). Similar to the June contract, the high-low trading time variances indicate that the differential between the volatility of the CBOT morning trading and LIFFE trading for the September contract is smallest in 1988. For the December contract, the high-low trading time variance is actually greatest for the LIFFE session (.220 for the LIFFE and .169 for the CBOT morning trading). Although not reported in this study, the anlysis of interday high-low trading time variances indicate that the relatively high variance of the LIFFE trading for the December 1988 U.S. Treasury bond futures contract is primarily due to unusually high volatility on Friday and Wednesday.

In sum, the high-low trading time variances of the U.S. Treasury bond futures exhibit a pattern that is consistent with the pattern observed when return volatility is estimated with the Maximum likelihood estimator of a normal distribution. Moreover, the pattern generally exists for various subperiods considered. No year or contract month effects are detected in the patterns of high-low trading time variances for the period chosen in this study. In the next section results based on the high-low trading time variance estimator for the Eurodollar futures is presented.

4.4.2 <u>Eurodollar Futures: Trading Time High-Low Variance Estimator</u>

If the differential between the volatility of various markets is related to uneven flow of information over time as well as differences in the level of liquidity and trading costs of the markets then the high-low variance of the Eurodollar futures contract should be greater during the hours of the primary market (CME) than during the hours of overseas markets (LIFFE and SIMEX). In Table 17 (p. 108), the high-low trading time variances are reported for the period from January, 1987 to November, 1988 as well as for 1987 and 1988 separately. The reported overall results are consistent with this expectation. For various time periods, the greatest high-low variance is obtained for the CME trading hours (7.20 a.m. to 2 p.m). The second greatest high-low variance is that of the LIFFE trading hours (2.30 a.m. to 10 a.m.) and the lowest variance is that of the SIMEX trading hours (6.30 p.m. to 2.30 a.m.).

Similar to the U.S. Treasury bond futures, the high-low variances of the Eurodollar futures in 1988 are lower than those in 1987. Likewise, the high-low trading time variances for individual contracts in 1988 are mostly lower than their counterparts in 1987, suggesting that the overall differential between 1987 and 1988 is not due to unusual

TABLE 17

Eurodollar Futures:
High-Low Variances of Trading Sessions.

Session:	SIMEX	LIFFE	CBOT	Number of days
January 5, 1987 to November 29, 1988				
Mon.-Fri.	.00126	.00294	.00469	376
Mon.-Thurs	.00134	.00242	.00405	308
January 5, 1987 to December 31, 1987				
Mon.-Fri	.00179	.00334	.00562	195
Mon.-Thurs	.00193	.00285	.00506	162
January 4, 1987 to November 29, 1988				
Mon.-Fri	.00069	.00249	.00371	181
Mon.-Thurs	.00068	.00195	.00295	146

Notes:

1. The hours of the SIMEX are 6.30 p.m. to 2.20 a.m. (since the trading on LIFFE begins at 2.30 a.m., the LIFFE opening price is substituted for the SIMEX closing price).
2. The hours of the LIFFE are 2.30 a.m. to 10 a.m.
3. The hours of the CME are 7.20 a.m. to 2 p.m.

volatility associated with particular contract(s) within either year (results available from the author). Thus, the results in Table 17 indicate that for the time period chosen in this study, no year or contract month effects is present in the distribution of the Eurodollar futures high-low trading time variances.

4.5 Trading and Non-Trading Time Variances: Impact of Information Release Days

Results in previous sections (4.1 to 4.4) have shown that variances differ between trading and non-trading as well as between trading sessions of the markets for the U.S. Treasury bond futures and Eurodollar futures. Moreover, tests based on two alternative estimators of variances and various time periods have indicated that the observed variance differentials are consistent with the Information hypothesis. To investigate the relationship between the arrival of information and the nonstationarity of variances, tests of the impact of public macroinformation releases on the pattern of trading and non-trading time variances of the two futures contracts are undertaken and the results reported in the following sections.

4.5.1 U.S. Treasury Bond Futures: Impact of Macroinformation Releases

Macroinformation releases chosen for the analysis are the Merchandise Trade Balance (TB), the Industrial Production (IP), the Consumer Price Index (CPI), and the

Money Supply (MS). The impact of U.S., U.K., and Japanese releases on the U.S. Treasury bond futures trading and non-trading time variances are tested in this section. For the period from May, 1987 to November, 1988, the return variances for trading and non-trading sessions are reported for days with information releases (from U.S., U.K., and Japanese markets) as well as for days when no information releases take place. Comparing the return variances of the U.S. Treasury bond futures on these two groups of calendar days reported in Table 18 (p. 111), the variances of sessions 3 (.153), 4 (.120) and 6 (.045) on information release days are greater than those of similar sessions on days with no information releases (.105 .111, .036, respectively) while the variances of sessions 1,2, and 5 are greater on days with no information releases. The differences in variances for the two groups of days are significant at 1% level for sessions 1 to 4. To the extent that the return variances of the U.S. Treasury bond futures are affected by the releases of the chosen macroinformation, the impact of the information is evident during trading session 3 (2.15 a.m. open LIFFE to 8 a.m. open CBOT), and to a lesser degree in session 4 (8 a.m. open CBOT to 10.10 a.m. close LIFFE). The variances of session 3 on information release days and days with no information releases are .153 and .105, respectively. The variances of session 4 on the

TABLE 18

U.S. Treasury Bond Futures:
Impact of Information Release Days.

Time period: May 5, 1987 to November 28, 1988

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Days with information releases							
	.034	.016	.153 (a)	.120 (a)	.168	.045	167
Days without information releases							
	.055	.035	.105	.111	.179	.036	157

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days without information releases at .01 level.

information release days and days with no information releases are .120 and .111, respectively.

To further examine the impact of information releases, tests of the information impact are undertaken for the U.S., U.K., and Japan separately. For U.S. macroinformation releases, return variances of various sessions on days with U.S. information releases and days without U.S. information releases are reported for all weekdays as well as for each weekday individually. Results in Table 19 (p. 113) indicate that for all weekdays combined, the variance of the U.S. Treasury bond futures in session 3 is greater than the variance of similar session for all days when all information releases are considered (.200 for U.S. information release days and .153 for all information release days). More importantly, the variance of session 3 on U.S. information release days is approximately twice that of similar session on days with no information releases. Specifically, the return variances of session 3 on Fridays, Wednesday, and Tuesday with U.S. information releases are .476, .253, and .224, respectively. All of these session 3 variances are significantly greater than the variances on similar weekdays without U.S. information days (.190, .068,and .040) as well as on all days without any information releases (.105). In addition, the return variance of session 4 on Tuesdays with U.S. information releases (.277) is significantly greater than the variance

TABLE 19

U.S. Treasury Bond Futures:
Impact of U.S. Information Release Days.

Time period: May 5, 1987 to November 28, 1988
I: Days with U.S. information releases
II: days without U.S. information releases

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.							
I.	.031	.016	.200 (a)	.124	.155	.040	109
II.	.052	.030	.091	.109	.182	.033	215
Mon.							
I. no U.S. information releases during this period							
II.	.059	.030	.053	.086	.161	.011	51
Tue.							
I.	.050	.004	.224 (a)	.277 (a)	.460 (a)	.028	11
II.	.046	.040	.056	.093	.135	.024	55
Wed.							
I.	.006	.007	.253 (a)	.071	.042	.006	12
II.	.073	.032	.068	.144	.189	.024	59
Thurs							
I.	.034	.018	.130	.076	.077	.034	71
II. Money Supply announcements are released on Thursdays							
Fri.							
I.	.023	.024	.476 (a)	.290 (a)	.429 (b)	.109	15
II.	.027	.019	.190	.108	.231	.078	50

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days without U.S. information releases at .01 level.
b: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days without U.S. information releases at .05 level.

of Tuesdays without U.S. information releases (.093) as well as the variance of days without information releases (.111). Thus, results in Tables 18 and 19 suggest that U.S. information releases can have significant impact on the variances of U.S. Treasury bond futures contract.

The impact of the chosen U.K. macroinformation releases on the variance pattern of the U.S. Treasury bond futures can be seen in the results presented in Table 20 (p.115). For all weekdays combined, the return variance in trading session 4 (8 a.m. open-CBOT to 10.10 a.m. close-LIFFE) on days with U.K. information releases (.166) is greater than the variance of similar session on days without U.K. information releases (.102) as well as on all days without any information releases (.111). On a weekday basis, the variance of session 4 on Fridays and Wednesdays with U.K. information releases are particularly high (.296 and .667, respectively). In addition, the variance of session 3 on Fridays with U.K. information releases is also relatively large at .259. The relatively high return variance of session 3 is expected provided that most of the chosen U.K. information tends to be released in the afternoon of U.K. trading hours, and that the reaction of the traders to U.K. information takes place between 8 a.m. to 10 a.m. Chicago time.

The impact of similar macroinformation series generated in Japan are also examined. The impact of the Japanese

TABLE 20

U.S. Treasury Bond Futures:
Impact of U.K. Information Release Days.

Time period: May 5, 1987 to November 28, 1988
I. Days with U.K. information releases
II. Days without U.K. information releases

Session	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.							
I.	.046	.020	.089	.166 (a)	.150	.025	57
II.	.045	.027	.136	.102	.177	.038	267
Mon.							
I.	.090	.020	.066	.062	.089	.004	17
II.	.045	.035	.047	.099	.200	.014	34
Tue.							
I.	.040	.006	.029	.052	.202	.041	9
II.	.049	.038	.095	.133	.171	.022	57
Wed.							
I.	.023	.020	.127	.667 (a)	.181	.005	6
II.	.065	.029	.078	.095	.164	.023	65
Thurs.							
I.	.025	.020	.058	.122	.054	.048	15
II.	.036	.018	.150	.059	.075	.031	56
Fri.							
I.	.034	.036	.087	.259	.296	.030	10
II.	.025	.017	.287	.123	.257	.094	55

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days witout information releases at .01 level.

releases are shown in Table 21 (p. 117). For all weekdays, Japanese information may have an impact on the variance of the U.S. Treasury bond futures in trading session 5 (2 p.m. to 6 p.m. Chicago time). The return variance for this session on Japanese information days is .190 which is greater than the variance of similar session on days without Japanese information releases as well as days with no information releases. However, the relatively large variance of session 5 appears to be due a large variance that is based on only three Fridays with Japanese information releases. As a result, it is difficult to reliably generalize the impact of Friday session 5 variance the overall (all weekdays) variance of similar session.

To further investigate the impact of the four macroinformation releases (TB, IP, MS, and CPI), the variances on days that only U.S. information is released are examined. Likewise, the variances on days with U.K. releases only and days with Japanese information releases only are considered. The results for U.S. information days reported in Table 22 (p. 118) show that the variance of session 3 (2 a.m. to 8 a.m.) which has been shown to be relatively large on all information days (.153) and days with U.S. information releases (.200) remains large (.224) on days with only U.S. information releases. The variance of session 4 (8 a.m. to 10.10 a.m.) which has the magnitude of .120 and .124 on all information days and days with U.S.

TABLE 21

U.S. Treasury Bond Futures:
Impact of Japanese Information Release Days.

Time period: September 9, 1987 to November 28, 1988
I. Days with Japanese information releases
II. Days without Japanese information releases

Sessions:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Mon.-Fri.							
I.	.022	.009	.055	.106	.190	.034	31
II.	.039	.029	.138	.111	.156	.023	227
Mon.							
I.	.020	.011	.048	.072	.138	.013	24
II.	.096	.047	.058	.101	.187	.007	27
Tue.							
I. Since there were only 2 information releases, the variances are not reported.							
II.	.037	.041	.099	.119	.152	.024	50
Wed.							
I. Since there were only 2 information releases, the variances are not reported.							
II.	.034	.031	.089	.106	.167	.017	51
Thurs.							
I. No Japanese information was released on Thursdays during this period.							
II.	.030	.016	.146	.075	.068	.030	54
Fri.							
I. Since there were only 3 information releases, the variances are not reported.							
II.	.022	.018	.262	.157	.200	.031	5

TABLE 22

U.S. Treasury Bond Futures:
Impact of Nonoverlapping U.S., U.K, and Japanese
Information Release Days.

Time period: May 5, 1987 to November 28, 1988

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Days with only U.S. information releases							
	.030	.016	.224 (a)	.092	.162	.059	88
Days with only U.K. information releases							
	.066	.022	.048	.100	.159	.019	28
Days with only Japanese information releases							
	.020	.009	.038	.069	.188	.042	23
Days with no information releases							
	.055	.035	.105	.111	.179	.036	157

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days with no information releases at all at .01 level.

information releases becomes smaller (.092) for days with only U.S. information releases. On days when only U.K. releases are made, the variance of session 4 also becomes smaller at .100 while the variance of similar session on days with U.K. releases is .166. The variances of days with only Japanese information releases do not change significantly from those obtained for days with Japanese releases. In sum, results in Table 22 tend to suggest that for the period chosen in this study, the U.S. information has significant impact on the pattern of variances of the U.S. Treasury bond futures. In contrast, similar information released in the U.K. and Japan does not have the same level of impact on the variances of the U.S. Treasury bond futures.

Results reported earlier in Table 19 show that on days of U.S. macroinformation releases, the U.S. Treasury bond futures return variances of session 3 (2 a.m. to 8 a.m.) on Fridays (.476), Wednesdays (.253), Tuesdays (.224), and Thursdays (.130) are greater than the variance of similar session on days with no information releases (.105). The relatively large return variance on these weekdays is consistent with the distribution of the Merchandise Trade Balance (TB) and Consumer Price Index (CPI) figures across weekdays. During the time period analyzed in this study, the majority of TB releases were on Fridays and the rest were distributed almost evenly on Thursdays, Wednesdays, and

Tuesdays while the majority of CPI releases were on Fridays and the rest were on Wednesdays and Tuesdays. In addition, during the period considered TB and CPI releases were made at 7.30 a.m. Chicago time. To the extent that information contained in these two releases is relevant to the U.S. Treasury bond futures trading, the variance patterns observed for days with these information releases suggest that the market participants begin to trade on the arriving information during the time period immediately preceding the release time and continue to trade on information after the release has taken place.

Since the U.S. macroinformation chosen appears to have an impact on the variance pattern of the U.S. Treasury bond futures, days on which each of the four macroinformation releases take place are examined separately. Variances of trading and non-trading sessions on days with U.S. TB, IP, CPI, and MS releases are presented in Table 23 (p.121). The variance of session 3 (2 a.m. to 8 a.m) for days with TB and IP releases in the U.S. is 0.714 and 0.437, respectively. The variance of the same session on days of CPI releases and MS releases is .052 and .130, respectively. Relative to days with no information releases, the variance in session 3 of TB and IP release days is 3 to 6 times greater than the variance of similar session for days when none of the four macroinformation is released (.105). In addition, on days with IP releases and days with CPI releases in the U.S., the

TABLE 23

U.S. Treasury Bond Futures:
Impact of U.S. Merchandise Trade Balance, Industrial Production, Consumer Price Index, and Money Supply Release Days.

Time period: May 5, 1987 to November 28, 1988

Session:	(1)	(2)	(3)	(4)	(5)	(6)	Number of days
Days with U.S. Merchandise Trade Balance releases							
	.018	.019	.714 (a)	.193	.243	.011	17
Days with U.S. Industrial Production releases							
	.024	.011	.437 (a)	.169	.378 (b)	.037	18
Days with U.S. Consumer Price Index releases							
	.031	.010	.052	.202	.160	.079	16
Days with U.S. Money Supply releases							
	.034	.018	.130	.076	.077	.034	71
Days without any information releases							
	.055	.035	.105	.111	.179	.036	157

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session for days with no information releases at .o1 level.
b: Using standard F-test, the variance of the session is significantly greater than the variance of similar session for days with no information releases at .05 level.

variance of session 4 (8 a.m. to 10.10 a.m.) is greater than that of session 4 for days without information releases (.169, .202, and .111, respectively). On Thursdays when the U.S. MS released is made after the financial markets are closed, only the variance of session 3 (.130) is greater than the variance of similar session on days with no releases. Overall, the patterns of variances reported for each category of U.S. macroinformation suggest that for the time period examined, the U.S. Merchandise Trade Balance has the most pronounced impact on the U.S. Treasury bond futures return variances. The U.S. Industrial Production and Consumer Price Index can also affect the pattern of variances for days that the releases are made. The U.S. Money Supply releases, on the other hand, do not have any notable impact on the U.S. Treasury bond futures variances.

4.5.2 Eurodollar Futures: Impact of Macroinformation Releases

In this section the analysis of the impact of the four macroinformation releases (TB, IP, CPI, and MS) in the U.S., U.K., and Japan on the trading and non-trading time variances of the Eurodollar futures is presented. Results indicate that the variances of the trading and non-grading sessions for days with information releases and days without any information releases are not significantly different. However, while the overall variance pattern for all information days may not differ from that for non-information days, it is still possible that the variance pattern specific to days with certain type of information releases may be different from the pattern of variance for days with no information releases. Shown in Table 24 (p. 124) are the variances for three categories of days namely, days with U.S., U.K., and Japanese information only. While the variances for each category of days are not significantly different from those of days when there are no releases for each type of information, the variances on days with U.S. information only warrant further examination. Although not statistically significant, a differential exists between the variances of session 3 (7.20 a.m. to 10 a.m.) for days with U.S. information releases and days with no information releases (.0040 versus .0032). Since the Merchandise Trade Balance (TB) and the Consumer Price Index (CPI) were released at 7.30 a.m. Chicago time, the variance of session 3 on days with U.S. information may reflect the market's reaction to the two information releases.

Shown in Table 25 (p.125) are the variances of the Eurodollar futures for four categories of days namely, those with U.S. TB, IP, and CPI releases, respectively. Since all three releases were made during 7.20 a.m. to 8.30 a.m., their impact on the Eurodollar variance pattern should be most pronounced during session 3 which covers the time interval from 7.20 a.m. to 10 a.m. Results indicate that the only the variance of session 3 for days with TB releases

TABLE 24

Eurodollar Futures:
Impact of Information Release Days.

Time period: January 5, 1987 to November 29, 1988

Sessions:	(1)	(2)	(3)	(4)	(5)	Number of days
Days with information releases	.0014	.0008	.0025	.0023	.0009	171
Days without information releases	.0010	.0009	.0032	.0027	.0009	205
Days with only U.S. information releases	.0017	.0007	.0040	.0018	.0013	98
Days with only U.K. information releases	.0014	.0014	.0010	.0025	.0006	30
Days with only Japanese information releases	.0003	.0004	.0007	.0020	.0004	19

TABLE 25

Eurodollar Futures:
Impact of U.S. Merchandise Trade Balance, Industrial Production, Consumer Price Index, and Money Supply Release Days.

Time period: January 5, 1987 to November 29, 1988

Session:	(1)	(2)	(3)	(4)	(5)	Number of days
Days with U.S. Merchandise Trade Balance releases						
	.0004	.0004	.0094 (a)	.0017	.0004	15
Days with U.S. Industrial Production releases						
	.0015	.0007	.0031	.0034	.0008	18
Days with U.S. Consumer Price Index releases						
	.0020	.0008	.0031	.0023	.0023	19
Days with U.S. Money Supply releases						
	.0016	.0007	.0012	.0016	.0006	77
Days with no information releases						
	.0010	.0009	.0032	.0027	.0009	205

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days with no information releases at .01 level.

(.0094) is significantly greater than the variance of similar period on non-information days (.0032). The differential between session 3 variances is consistent with the view that the three U.S. macroinformation releases can affect the volatility of the Eurodollar futures. In addition, while not statistically signicant, a positive differential between the variance of session 4 (10 a.m. to 2 p.m.) for days with U.S. IP releases and days with no information releases does exist (.0034 versus .0032). The greater magnitude of session 4 variance for days with U.S. IP releases may reflect the market's delayed reaction to information relevant to the Eurodollar futures trading that is contained in the IP releases.

To further disentangle the impact of U.S. TB, IP, and CPI releases on the volatility of the Eurodollar futures contract, the variances of the Eurodollar futures on days with U.S. TB releases only, days with U.S. IP releases only, and days with U.S. CPI releases only are examined. Results in Table 26 (p. 127) show that on TB-only release days, the variance of session 3 (7.20 a.m. to 10 a.m.) is more than 5 times greater than the variance of session 3 on days with no information releases (.0174 versus .0032). The greater session 3 variance on TB-only release days suggests that traders concentrate their trading on information contained in the TB releases during the time interval immediately following the scheduled release. In addition, the variance

TABLE 26

Eurodollar Futures:
Impact of Nonoverlapping U.S. Merchandise Trade Balance, Industrial Production, Consumer Price Index, and Money Supply Release Days.

Time period: January 5, 1987 to November 29, 1988

Session:	(1)	(2)	(3)	(4)	(5)	Number of days
Days with only U.S. Merchandise Trade Balance releases						
	.0005	.0003	.0174 (a)	.0020	.0010	5
Days with only U.S. Industrial Production releases						
	.0024	.0009	.0025	.0049	.0014	11
Days with only U.S. Consumer Price Index releases						
	.0020	.0008	.0030	.0023	.0022	19
Days with only U.S. Money Supply releases						
	.0018	.0007	.0008	.0017	.0010	69
Days with no information releases						
	.0010	.0009	.0032	.0027	.0009	205

a: Using standard F-test, the variance of the session is significantly greater than the variance of similar session on days with no information releases at .05 level.

of session 1 which represents the SIMEX trading hours (6.30 p.m. to 2.30 a.m) for IP-only release days (.0024) and CPI-only release days (.0020) are significantly greater than the variance of similar session on non-information days (.0010). If traders who trade Eurodollar futures on the SIMEX also form their expectations regarding the information anticipated in the IP and CPI releases that will take place at the beginning of the next trading session on the CME, they may conceivably begin trading on their expectation in advance of the scheduled TB release time. As a result, the volatility of the SIMEX trading session can be relatively high prior to a TB release in the U.S.

Results of the analysis of macroinformation release effect on the volatility of the U.S. Treasury bond futures and Eurodollar futures contracts suggest that the four chosen macroinformation series namely, the Merchandise Trade Balance, the Industrial Production, the Consumer Price Index, and Money Supply varies in their impact on the variance patterns of the two futures contracts. In addition, the results indicate that the impact U.S. macroinformation dominates that of the U.K. and Japanese macroinformation. Moreover, the market tends to react quickly, although not instantaneously, to the release of certain macroinformation (i.e., U.S.-released IP, TB, and CPI) as the volatility of the affected futures contract is observed to increase during time periods surrounding the release of a particular information. Lastly, there is also evidence of some advanced as well as delayed market's reaction to information releases. Overall, the results of the analysis indicate that non-stationarity in the distribution of the variances of the U.S. Treasury bond futures and Eurodollar futures is related to the arrival of certain macroinformation. However, types of information that affects the stationarity of variances can be period dependent.

CHAPTER 5

CONCLUSION

A growing body of evidence suggests that risk as measured by return variance is greater during the trading hours than during the non-trading hours of the markets for assets traded in the U.S. financial markets. Today, certain assets have multiple listings on various international markets. As international financial and capital markets become increasingly integrated, analysis of the effect of world-wide market listing on the variance distribution is required. This research has investigated the trading/non-trading time effect of variance in international markets. Specifically, the patterns of variances for U.S. Treasury bond futures and Eurodollar futures contracts across various international trading and non-trading sessions within the 24-hour period is analyzed. The results indicate that the trading/non-trading time effect existed in the distribution of variances for both the U.S. Treasury bond futures and Eurodollar futures during the time period examined. Alternative hypotheses have been tested as explanations for the observed trading/non-trading time effect. The analysis has provided evidence of a relationship between trading/non-trading time effect in the distribution of variances and the flow of information to the markets for these two futures contracts.

The major findings from this research are:

1. Return variances of the U.S. Treasury bond futures and Eurodollar futures contracts can differ significantly across various trading and non-trading sessions as well as between trading sessions of the international markets where these contracts are traded.[39] The return variances of the two futures contracts were greatest during the trading hours of the primary markets (CBOT and CME) in the U.S. which also coincide with part of the trading sessions of other financial markets in the United States as well as the United Kingdom. In contrast, the lowest variance existed in the time period during which the major markets for the two futures contracts are closed and the liquidity in the cash markets is reduced. Tests have indicated that the nonstationarity of return variances across time periods is not a strict function of the passage of calendar time or trading time. Rather, the results are consistent with the information/trading costs explanation. Evidence suggests that the differentials between return variances of differing trading and non-trading sessions are related to the uneven flow of information relevant to the U.S. Treasury bond futures and Eurodollar futures trading that tends to be released in time periods surrounding or during the trading sessions on the primary exchanges.

2. While no seasonality due to the year or contract month effects has been found for the period examined, the patterns

of variances of the U.S. Treasury bond futures and Eurodollar futures can vary slightly from year to year and from one quarter to another. Similarly, although no clear interday variance effect was present, the trading variances of the two futures contracts tended to be highest for Friday and lowest on Thursday. The trading/non-trading time effect was observed for the pattern of variances of all weekdays. In addition, the trading and non-trading effect continued to exist in the patterns of hourly variances. Thus, the nonstationarity in the variance distribution is not a strict function of hourly trading activity.

3. Holidays were shown to have an impact on the trading/non-trading time patterns of variances for the U.S. Treasury bond futures and Eurodollar futures contracts. The general effect of holidays and weekends in the sample is an increase in the magnitude of return variance of certain time period, which can significantly alter the overall patterns of trading and non-trading time return variances. In addition, evidence indicates that holidays in various international markets can have different impacts on the return variances of the U.S. Treasury bond futures and Eurodollar futures.

4. Results of the analysis were similar for the maximum likelihood estimator of the variance of a normal distribution and for an alternative extreme-value estimator of variance that is based on daily high and low prices recorded during the trading hours of the markets. Similar

to the S^2 estimator, the magnitude of the P^2 estimator of the daytime trading sessions of the U.S. futures markets (CBOT and CME) is greater than that of the trading session in the U.K. futures market (LIFFE). For the U.S. Treasury bond futures, the lowest high-low variance was observed for the evening trading session on the CBOT while for the Eurodollar futures the lowest high-low variance was that of the trading hours of the Singapore futures market (SIMEX).

5. Among the four macroinformation series considered in this study, the Merchandise Trade Balance, the Industrial Production, and the Consumer Price Index had the most pronounced effect on the patterns of return variances of the U.S. Treasury bond futures and Eurodollar futures during the time period chosen for the analysis. Results show that the return volatility of the two futures contracts during time periods associated with the trading on information contained in the news releases can differ from the volatility in similar time periods on days when none of the public information is released. Macroinformation released in the U.S. has the most pronounced impact on the return variances of the U.S. Treasury bond futures and Eurodollar futures. While there is evidence that similar information released overseas (U.K. and Japan) can also affect the trading/non-trading time variance patterns, the impact of information released outside the United States tends to be of smaller magnitude relative to the impact of U.S. releases.

This study contributes to research into the causes and characteristics of asset volatility as well as the effect of expanded information environment in international financial markets.[40] Further, the results have implications for financial models which form the foundations of various trading strategies. Risk estimate represents a principal parameter in various financial models. Missestimation of risk may have serious consequences for empirical testing of asset valuation models. If risk as measured by variance is non-constant across trading and non-trading periods of individual markets, investment strategies must likewise adjust for the nonstationarity of variance.

The results of this study have also led to issues that should be examined in future research. To further investigate the nonstationarity of variance and the impact of information arrivals, transactional data from various international markets may be used in the analysis. Moreover, since information environment can change over time, future research in this area should use longer time periods as well as different information sets that can affect the patterns of return variances.

Release dates data have been used in this study, expectational data (e.g., forecasts of information to be released) should be employed in future analysis of nonstationarity in return variance distribution. While information of similar nature is released overseas as well as in the U.S., institutional differences associated with the releases of information from various sources do exist (e.g., announcements and precision of release times, advance reports). Such differences can have an impact on the trading pattern (e.g., rumor trading) that should be examined. Moreover, future analysis needs to consider other types of information (e.g., random financial events reported in newspapers) along with public information released on a regular basis.

Since return variances of internationally traded assets can be affected by holidays, tests should be performed to determine the impacts of holidays in different countries on the pattern of variances. Differences may exist between the volatility in time intervals surrounding various categories of holidays.

Lastly, future research should examine the internal market dynamics such as the variance spillover effect in international markets. Nonstationarity of asset return variance can be affected by information arrival process as well as trading dynamics particular to the markets considered. Certain aspects of a trading dynamics such as the stationarity and strength of a spillover effect should be examined.

ENDNOTES

1. Other surrogates for asset risk also exist, for example, the semivariance and semideviation of return, and the semi-interquartile range. The semivariance and semideviation are usually calculated from only disappointingly low returns to measure the chance of loss associated with the left-hand tail of a probability distribution. Markowitz [94], however, demonstrates that when the probability distributions are symetrically distributed, the implications of mean-variance portfolio analysis are similar to the mean-semivariance results. Further, Markowitz points out that the variance (standard deviation) is superior to the semivariance (semideviation) in terms of cost, convenience, and familiarity. The semi-interquartile range is equal to half the difference between the 0.75 and 0.25 fractiles of the cumulative probability distribution. Fama and Miller [48] suggest that this risk surrogate should be used in the two-moment portfolio analysis involving return distributions without finite variance (e.g., certain stable non-normal Paretian distributions). When return distributions are non-normal, higher moments of the distribution may become relevant to the portfolio problem. Several studies (e.g., Kraus and Litzenberger [88], Beedles [11], Schweser and Schneeweis [121], Sears and Wei [122]) have examined asset pricing and portfolio models which incorporate the third moment, skewness, of the return distribution in addition to the first two moments. While alternative risk surrogates and higher distribution moments have implications for certain investment strategies, the analysis of the stationarity of these parameters, however, is not a part of this proposed study.

2. It should be noted that the definition of trading and non-trading periods is somewhat dependent on the researcher's classification of active and inactive markets. For example, the trading period in the U.S. stock market has commonly been defined as the hours when the NYSE is open despite the fact that some U.S. stocks are also traded during the hours of the Pacific Coast Stock Exchange as well as during the hours of certain overseas exchanges.

3. Variance can be alternatively calculated based on close-to-close, open-to-close, or transaction-to-transaction prices. All three methods of calculation have been used in studies of nonstationarity in variance distribution.

4. Possible explanation for nonstationarity of variance include the Calendar Time and Transaction Time hypotheses. More Recently, uneven information flow through time has received increased attention from researchers as a most

promising explanation for the observed differential between trading and non-trading time variances. Further research, however, is required to understand the exact nature of the relationshiop between information process and asset volatility.

5. Recently, researchers have begun investigating the trading/non-trading time effect and nonstationarity of variance in international markets. Major markets in which 24-hour trading currently exists are currencies, gold, oil, stocks, U.S. Treasury bond futures, and Eurodollar futures contracts. Review of selected studies which have examined some of these markets are presented in Chapter 2 of this study.

6. Associations between variance, information, and trading volume have been examined by Karpoff [85, 84], Jain, and Joh [80], Cornell [31], Grammatikos and Saunders [62], among others. Using simulation method, Karpoff [81] shows that the relation between volume and information is affected by the institutional design of the market. In markets with significant frictions, e.g., order backlogs, high volume may persist simply because time is required before all trades are cleared. Moreover, the tendency of stock trades to cluster at even eighths of price will tend to cause high volume when price changes to an even eighth (Merrick [97]). It has also been shown that the association between information and volume in futures trading cannot be unambiguously discernd due to arbitrage and program-trading activities. In this analysis, it is assumed that difference in volume between markets simply reflects the liquidity and transaction costs structure of various markets.

7. In using variance as a surrogate for asset risk, it is assumed that the population return distribution considered has a finite variance. If the population from which the sample return are drawn has finite second moment, then according to the Central Limit Theorem the observed return distribution can be approximated by a normal distribution with finite variance (Fama [47]). However, Fama [47] reports empirical evidence suggesting that daily and monthly returns on stocks are leptokurtic and may belong to the non-normal stable Paretian distribution with infinite variances. On the other hand, Hsu, Miller, and Wichern [73] argue that stock return distributions can be adequately represented by normal distributions with finite variances. Blattberg and Gonedes [14] point out that the observed leptokurtis in daily return distribution can also be explained by the Student-t distribution, thus avoiding the problem associated with infinite variance. Teichmoeller [127], Kon [87] suggest that daily returns could be modeled as a discrete

mixture of different distributions with finite second moments. Nelson [100] provides evidence that a wide variety of distribution shapes can actually exist for various futures contracts, although the generalities of leptokurtic nonnormal distributions reported in other studies seem to be the norm for most contracts. In this proposed study it is assumed that the U.S. Treasury bond futures and Eurodollar futures price changes are drawn from the distributions with finite though not necessarily stationary variances.

8. In practice most commercial services (e.g., Bloomberg) use 10, 30, or 60 days of returns to estimate variances for cash and futures assets.

9. In comparing trading and non-trading time variances, Fama does not consider weekend and holiday variances separately. Since the length of non-trading period differs between weekend and various holidays, the magnitude of the trading/non-trading time variance ratio can be sensitive to types of non-trading periods considered.

10. The timing of information releases during the day can also affect the observed intraday pattern of variance. These information releases include both firm-specific and market-wide information.

11. French and Roll also point out that in reality most information falls between private and public categories. The private/public information artificial dichotomy is used only to facilitate the analysis. In addition, privately generated information eventually becomes public knowledge as it is disseminated through the trading process (see Goldman and Sosin [60]).

12. Differences in transaction costs for various stocks can also affect the volatility during trading hours. For similar information flow, the volatility of 2 stocks can differ due to differential between the expected costs of trading on the information. Whether high or low transaction costs tend to lead to higher observed volatility is an empirical issue for future research.

13. Negative correlations can also be induced by bid/ask measurement errors. Bid/ask measurement errors occur because each closing trade may be executed at any price within the bid/ask spread. If these measurement errors are independent from day to day, then they will induce negative first-order autocorrelation (see also, Branch and Freed [19], Roll [115]).

14. Whether trading on noise as if it were information is an important factor in securities markets is an unsettled issue. The traditional view maintains that investors who trade on noise cannot survive in the long run (see, for example, Friedman [51], Figlewski [49]). This view has been challenged in some recent theoretical studies. Black [12] argues that noise trading must account for a significant proportion of total trading in securities markets. Truman [128] provides a theoretical model which describes investment fund managers who engage in noise trading for the reason that the level of the managers' trading provides positive signal about their ability to collect information on current and potential investments. De Long, Shleifer, Summers, and Waldman [35] argue that under certain assumptions, noise traders will survive and come to dominate the market in terms of wealth in the long run. The economic role of noise trading and its effect on volatility is not examined in this study.

15. While informed investors prefer to trade in periods of high liquidity, they are at the same time constrained by the decay in value of their information if they wait too long to trade. As pointed out by Kyle [89], public information also acts as a substitute for private information that is not timely traded on.

16. Investors' timing of trade may also be affected by individual firm's managerial decision making process. The timing of information releases is, in part, dependent upon the pattern in managerial decision making behavior. For example, management may holds regular meeting in early morning and tend to release significant news in late afternoon.

17. Brown, Harlow, and Tinic's results are inconsistent with evidence which suggests that investors tend to overreact to unexpected information (e.g., Debondt and Thaler [34]). Brown et al. argue that expost return pattern which appears to represent exploitable profits due to overreacting behavior is actually consistent with rational and efficient adjustments by investors to uncertain information. Thus, the observed pattern of expost abnormal returns is illusory since it is virtually impossible to predict the direction and magnitude of returns for individual event on a regular basis.

18. While NYSE presently offers the greatest volume and liquidity for the trading of U.S. stocks listed in on the NYSE as well as on exchanges in other countries, it is possible that the number of liquidity traders on foreign exchanges, e.g., LSE and TSE, will not remain small

permanently. The increase in the volume of liquidity trading on foreign exchanges will induce informed investors to shift some of their trading away from the NYSE, thus affecting the overall volatility of cross-listed stocks.

19. Results of analyses by Barclay et al. [6] and Makhija and Nachtman [93] can be sensitive to the size of their samples. For instance, it is not certain whether the sample of 16 NYSE-TSE listed firms is sufficiently large to capture changes in variance due to cross listing.

20. It should be noted that Phillips-Patrick and Schneeweis [109] recently provide some evidence suggesting that the "weekend effect" in S&P 500 Stock Index futures trading may not be as strong as shown by Dyl and Maberly's results. They demonstrate that the interest rate component of the carrying cost may partially account for the observed negative weekend futures return.

21. An interesting future research direction is to investigate the variance impacts of trading markets for different assets.

22. In this study, trading/non-trading time effect on mean price change will not be considered. The main reason is that the mean price changes obtained during periods in different time zones cannot be unambiguously compared since the timing and impact of each information arrival is not precisely known. As a result, prices in London or Singapore on one day cannot be compared with prices in Chicago on the same day. On the contrary, price change variances can be compared between markets since such comparison is not directly affected by the time zone effect and exact impact of each information arrival.

23. Markowitz [94] develops a theory of portfolio selection based on the mean/variance principle. The theory assumes that investors' preference and asset return distribution can be characterized by the first two distribution moments.

24. The return on investing in futures can also be viewed as the return on futures-cash arbitrage. Such return can be expressed as:

$$R = [(FP_{t+1} - FP_t) + r(CP_{t+1} - CP_t)]/CP_t$$

The computation of the arbitrage return requires the prices of the cheapest-to-deliver cash and the interest cost at various times. The arbitrage return should be used in future research on non-stationarity of variance to the extent that a large part of the 24-hour trading in the U.S.

Treasury bond futures may be associated with arbitrage activities. The use of ex post returns as proxies for expected returns may also introduce biases in the measurement of risk. If the true risk is the volatility of expected return over the holding period then risk as measured by return variance of expected return on a futures position is $Var(E(PF_{t+1} - PF_t))$.

25. See also Yau, Savanayana, and Schneeweis [132] on the effect on alternative return measures in financial futures research.

26. Garman and Klass [56] develop an estimator which incorporates information from the high, low, and closing prices. This estimator is not suitable to the analysis proposed in this study since it incorporates information reflected in close-to-close price movements, not open-to-close and close-to-open price movements.

27. It should be noted that the formulation of extreme-value estimators are based on a "trial and error" method to fit numerical values in the mathematical expression. In addition, to the extent that the return distributions of the U.S. Treasury bond futures and Eurodollar futures may not be strictly normally distributed, the Levene's statistics for test of equal variances may also be used. The Levine's statistics for the test of equal variances is a modified ANOVA.

28. For analyses of problems in price data from thin markets see, for example, Scholes and Williams [119], Dimson [38], Blume and Stambaugh [15].

29. Since the October 1987 market crash was a unique, random event, the period surrounding the Crash (October 7 to 26, 1987) is excluded from the sample. In addition, the sample of Eurodollar futures prices does not include the month of October, 1988 due to missing data from the SIMEX at the time of the analysis.

30. See also French and Roll [54] on the effect of relaxing some of these assumptions.

31. See also Oldfield and Rogalski [105] on similar tests for stocks.

32. Since the U.S. Treasury bond futures and Eurodollar futures contracts are traded in markets in different time zones, it is necessary to establish a particular time as the starting point of the 24-hour close-to-close "day". Since the U.S. markets are the principal markets of these

contracts, the close of the CBOT, and CME will be defined as the starting point of the 24-hour "day" for U.S. Treasury bond futures and Eurodollar futures respectively.

33. In order to allow for leakages, information anticipation effect, and resolution of information uncertainty, alternative periods surrounding information releases will be considered in the assessing information impacts on variance pattern. Except for the money supply announcements which are released in the afternoon, the other announcements are usually made in the morning. While information impacts considered in this study include both anticipated and unanticipated portions, we would expect to detect the increase in volatility in surrounding periods as long as investors differ in their individual analysis of the eventual impact of a particular information release. The impact of unanticipated information could be assessed in future study by employing market-wide forecasts such as the consensus balance of trade forecast of 100 economists provided by MMS International.

34. The returns on the two futures contracts are calculated as the percentage form of the continuously compounded price relative:

$$R_t = \ln(P_{te}/P_{tb})*100$$

The analysis is also performed using the percentage price change:

$$R_t = [(P_{te} - P_{tb})/P_{tb}]*100$$

Results are similar to those using the percentage form of the continuously compounded price relative.

35. Trading in the cash assets is possible after the hours of the major exchanges at smaller exchanges that operate in a different time zone, e.g., the Pacific Stock Exchange.

36. Holidays are defined as those days with a return associated with time interval that is longer than an overnight period. While not examined in this study directly, the impact of different types of holiday, for instance, exchange and business holidays on the variance distribution in international markets should be explored in future research. The analysis undertaken in this study is based on samples from which holidays have been excluded to control for the impact of holidays that may confound the analysis of information and trading/non-trading time effect in the variance pattern.

37. During the period examined, SIMEX holidays constitute approximately half of all holidays.

38. While not reported in the study, the analysis has also been performed with prices from one month and two months of the nearby contract. while the magnitude of the variances can change (the maturity effect), the general pattern of trading/non-trading time variances remains unaffected by alternative uses of subsamples for each contract month.

39. This study uses historical variance as a proxy for asset risk, future study should examine implied volatility as an alternative risk measure.

40. The focus of the proposed analysis is on the "pure" information effect on volatility pattern of the U.S. Treasury bond futures and Eurodollar futures. Future research should also examine the characteristics of internal market dynamics such as the variance spillover effect between markets. While relationships of open-to-close price movements between markets are expected to exist, the strength, pattern, and stationarity of such dynamics remains to be examined. A methodology that may be used to analyze the market dynamics is based on the Autoregressive Conditional Heteroskedastic (ARCH) and Generalized Autoregressive Conditional Heteroscedastic (GARCH) developed by Engle [40] and Bollerslev [16], respectively. While ARCH and GARCH models have been extensively used in the finance literature (Engle et al. [44], Hamao and Masulis [66]), the implications of some of the assumptions of the models should also be explored.

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